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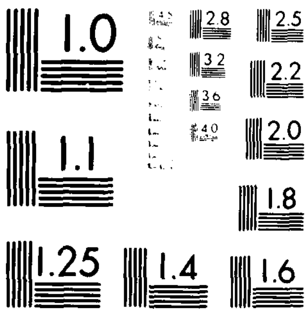

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A STUDY OF EMBEDDED COMPUTER SYSTEMS SUPPORT

VOLUME II

SELECTED ECS SUPPORT ISSUES: RECOMMENDATIONS/ALTERNATIVES

September 1980

APPROVED FOR PUBLIC RELEASE
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CDRL 02A
Contract Number F33600-79-C-0540

Prepared for
Air Force Logistics Command AFLC/LOEC
Wright Patterson AFB, Ohio 45433

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The primary purpose of volume two is to present a series of icey support issues that face today's Embedded Computer Support (ECS) Managers. It presents some of the background that has led to today's ECS support posture and a brief summary of the key findings of the analysis of the Air Force Logistics Command's current support posture. (See related volumes: LD 47169A, C, D, E, F, G, H, J, K and L).

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FOREWORD

This volume is one of nine individually bound volumes that constitute the Phase II Final Report "Study of Embedded Computer Systems Support" for Contract F33600-79-C-0540. The efforts and analyses reported in these volumes were sponsored by AFLC/LOEC and cover a reporting period from September 1979 through September 1980.

The nine volumes are

Volume	Title
I	Executive Overview (CDRL 05)
II	Selected ECS Support Issues: Recommendations/ Alternatives (CDRL 02A)
III	Requirements Baseline: Aircrew Training Devices (CDRL 02A)
IV	Requirements Baseline: Automatic Test Equipment (CDRL 02A)
V	Requirements Baseline: Communications-Electronics (CDRL 02A)
VI	Requirements Baseline: Electronic Warfare (CDRL 02A)
VII	Requirements Baseline: Operational Flight Programs (CDRL 02A)
VIII	ECS Technology Forecast (CDRL 03)
IX	National Software Works Investigation (CDRL 04)

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CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Concluded)

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ILLUSTRATIONS

ABBREVIATIONS AND ACRONYMS

AABCP	Advanced Airborne Command Post
ADP	Automatic Data Processing
ADPE	Automatic Data Processing Equipment
A-E	U. S. Army Engineers
AEP	Annual Engineering Plan
AFM	Air Force Manual
AFR	Air Force Regulation
AFRCE	Air Force Regional Civil Engineer
AIL	Avionics Integration Laboratory
AISF	Avionics Integration Support Facility
ATC	Aircrew Training Command
ATD	Aircrew Training Device
ATE	Automatic Test Equipment
AWACS	Airborne Warning and Control System
BP	Budget Program
C^3	Command, Control, and Communications
CAC	Combined Arms Concept
CBO	Congressional Budget Office
C^3CM	Command, Control, and Communications Countermeasures
CDR	Critical Design Review
C-E	Communications-Electronics
CEP	Contract Engineering Project
CI	Configuration Item
CM	Configuration Management
CMAC	Computer Monitor and Control
CMP	Configuration Management Plan
CORPS A-E	Corps of U. S. Army Engineers
CPCI	Computer Program Configuration Item
CPIN	Computer Program Identification Number
CPU	Central Processing Unit
CRISP	Computer Resources Integrated Support Plan
CRRG	Computer Resources Review Group
CRWG	Computer Resources Working Group

CY	Calendar Year
DAR	Defense Acquisition Regulations
DCP	Defense Coordinating Paper
DE	Diagnostic Emulation
DEPS	Development Engineering Prototype Site
DI	Data Item
DI	Design Instruction
DID	Data Item Description
DOD	Department of Defense
DODD	Department of Defense Directive
DPML	Deputy Program Manager for Logistics
DT&E	Development Test and Engineering
DSARC	Defense Systems Acquisition Review Council
EAROM	Electrically Alterable Read-Only Memory
ECCM	Electronic Counter Countermeasures
ECM	Electronic Countermeasures
ECR	Embedded Computer Resource
ECS	Embedded Computer System
EDMS	Engineering Data Management System
EE	Electrical Engineering
EEIC	Element of Expense Investment Code
EEROM	Electrically Erasable Read-Only Memory
EIA	Electronic Industries Association
EID	Emitter Identification Data
EOP	Engineering Objective Plan
EPROM	Erasable Read-Only Memory
EW	Electronic Warfare
EWIR	Electronic Warfare Integrated Programming
EWOLS	Electronic Warfare Open Loop System
FCA	Functional Configuration Audit
FLTS	Flight Line Test System
FPM	Federal Personnel Manual
FRC	Facility Requirements Committee
FSC	Federal Supply Class
FSED	Full-Scale Engineering Development
FTD	Foreign Technology Division

FY	Fiscal Year
FYDP	Five-Year Defense Plan
GAO	Government Accounting Office
GLDT	Generic Logistic Decision Tree
GSA	General Services Administration
HDBK	Handbook
HOL	High Order Language
HUMINT	Human Intelligence
H/W	Hardware
ICE	In-Circuit Emulator
ICS	Interpretative Computer Simulation
IFB	Invitation for Bid
IFF	Identification Friend or Foe
IG	Inspector General
ILSP	Integrated Logistic Support Plan
I/O	Input/Output
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
ISF	Integration Support Facility
IV&V	Independent Verification and Validation
JLC	Joint Logistics Commanders
JTIDS	Joint Tactical Information Distribution System
LCC	Life Cycle Costs
LRU	Line Replaceable Unit
LSI	Large Scale Integration
MAJCOM	Air Force Major Commands
MCP	Military Construction Program
MDR	Materiel Deficiency Report
MDS	Microcomputer Development System
MES	Management Engineering Squadron
MFP	Major Force Program
MIL-STD	Military Standard
MIP	Material Improvement Project
MMECOI	Operating Instruction of MMEC
MMOI	Operating Instruction of MM

MOA	Memorandum of Agreement
MPS	Microcomputer Prototype System
MTBF	Mean-Time Between Failures
NATO	North Atlantic Treaty Organization
OFP	Operational Flight Program
OI	Operating Instruction
OJT	On-the-Job Training
O&M	Operation and Maintenance
OMB	Office of Management and Budget
OOB	Operations Operating Budget
OPR	Office of Primary Responsibility
O&S	Operations and Support
O/S CMP	Operational/Support Configuration Management Procedures
OSD	Office of the Secretary of Defense
PAR	Program Assessment Review
PB	Project Books
PBD	Program Budget Decision
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PE	Personnel Equivalent
PL	Public Law
PMD	Program Management Directive
PMP	Program Management Plan
PMRT	Program Management Responsibility Transfer
POM	Program Objectives Memorandum
PROM	Programmable Read-Only Memory
QRSC	Quick Reaction Software Capability
RAM	Random Access Memory
REC	Radio Electronic Combat
ROM	Read-Only Memory
RWR	Radar Warning Receiver
SAC	Strategic Air Command
SEA	Southeast Asia
SHP	Simulation Host Processor
SIGINT	Signal Intelligence
SM	System Manager

SPO	System Program Office
SRAM	Short Range Attack Missile
SRR	System Requirements Review
SSC	Software Support Center
SUP	Supplement
S/W	Software
TAC	Tactical Air Command
TCTO	Time Compliance Technical Order
TDY	Temporary Duty
T.O.	Technical Order
TRC	Technical Repair Center
TRR	Test Requirements Review
UDS	Universal Development System
UUT	Unit Under Test
V&V	Verification and Validation
VHSIC	Very High Speed Integrated Circuits
VLSI	Very Large Scale Integration
WBS	Work Breakdown Structure

1. INTRODUCTION

The primary purpose of this volume is to present a series of key support issues that face today's ECS support managers. This section will present some of the background that has led to today's ECS support posture, a brief summary of the key findings of the analysis of AFLC's current support posture, and an introduction to the key support issues to be discussed in this volume.

Finally, Appendix A of this volume presents a series of recommendations that would improve AFLC's current support posture, if implemented. Table A-1 includes recommendations that can be implemented via management directives or direct management action. Table A-2 includes recommendations that most likely will require some form of programmatic action to implement.

1.1 BACKGROUND

Historically, the role of AFLC has been to provide support to TAC, SAC, and the other operational commands by ensuring that all Air Force systems were operational through buying, supplying, transporting, and maintaining systems and systems components. Accordingly, repair and modification facilities were conceived and established, large quantities of spares were projected and procured, and a logistics system evolved to facilitate distribution of needed support to worldwide locations.

The requirements of supporting Embedded Computer Systems (ECS) have significantly altered logistic support requirements. The responsibility for making modifications to systems (especially those with embedded computer systems such as the F-111, F-4, and F-16) has been, or in the future will be, transitioned to the Logistics Command from AFSC. The acquisition of support systems for embedded computer systems, including Integration Support Facilities (ISF's) and the engineering that is prerequisite to deciding technical issues about embedded computer software modifications or support systems, constitutes an engineering intensive program and has the characteristics of a high technology modification program.

Within the last ten years or so, the requirements for supporting systems which contain embedded computer systems have emerged. The fact that computers are embedded indicates a more versatile yet complex system. In other words, avionics devices have migrated from simple, independent components to complex, interdependent systems whose modification requires a much higher degree of sophisticated system knowledge and analysis. The computer software of newer systems is interrelated with the system design, and system capability can often be changed by altering only the software. Although software controlled systems offer added flexibility, the support requirements now are directly coupled to the operational success of the system. Where older systems lent themselves to separation of development and support, the newer systems are not distinguishable between the development and support aspects. Thus it follows that for embedded computer systems there is an overlap in the traditional AFSC and AFLC responsibilities and it is no longer obvious where the responsibilities for system acquisition and major modifications stop and the responsibilities for logistics support begin. This overlap has caused AFLC to enter the realm of engineering intensive support. The involvement of AFLC in this highly technical arena has evolved so gradually over the past several years that its impact was never seen as a newly identified problem which would have to be mastered. In essence, the AFLC migration into engineering intensive activities has been gradual, but is now very pronounced and an important part of AFLC activities. Because Air Force weapon system capability and military readiness are directly coupled to software support, the necessity for establishing an effective support posture is directly mission related and of grave importance.

The changing role in AFLC is symptomatic of changes in technology. Technological advances have occurred in virtually all aspects of weapon system function, thus, the weapon system capabilities have improved as the systems have become more sophisticated and complex. The trend toward more sophisticated systems encompassing embedded computer systems as an essential part of system structure is expected to accelerate in the future. Very High Speed Integrated Circuits (VHSIC), fiber optics, microprocessors, distributed processing using embedded computers, and

computer memory developments are but a few of the rapidly changing technologies that will mandate changes in AFLC policy and management if maintenance and support are to keep pace with the Air Force's needs. Software and/or firmware is playing an active and expanding role in each of these technologies so the trend will be toward more software as an inherent part of future weapon systems. Costs of system acquisition have migrated from being hardware driven to a mixture of hardware and software, with the future predicted to be heavily software driven. Translated, software costs affect labor costs rather than material costs.

Management for both development and support of embedded computer systems is engineering intensive because the tasks themselves are more technical and complex. Interrelated systems using software require more sophisticated engineering design or else the entire system capability is jeopardized. Since both the management and technical trends are more toward engineering tasks, it appears that some realignment of AFLC policy and procedures is required. For example, engineering support has always been a portion of total logistics support; but, as the engineering support occupies a larger portion of the total logistics support, the question arises as to whether the traditional AFLC priorities and procedures can be efficiently applied. The trend also is toward more and more expertise to analyze technical deficiencies and/or anomalies of the systems. This trend requires both hardware and software knowledge that applies to the weapons or avionics systems as well as the associated support systems. Similar trends are occurring within civilian industrial realms and, consequently, the overall competition for engineering talent is increased.

Typically, the problems associated with supporting embedded computer systems have been categorized into two types: technology related and management related. Closer examination indicates the management related problems are only symptomatic of the technology related problems, and because the AFLC role is changing into more technological involvement, the reaction to this involvement causes management perturbation. Realization that problems exist does not indicate that AFLC management personnel are negligent or are not doing their job, but rather the existent management practices do not efficiently apply to the changed AFLC role.

Prior to addressing some of the existent problems/issues within AFLC which are a by-product of the changing role of AFLC, it is appropriate to note that there are areas where much has been accomplished. In other words, the AFLC response to the changing role is not one of failure, but one of success with a concern to be even more successful. Although self-criticism is offered by internal AFLC elements about lack of accomplishment in adjusting to the new role, the fact is that many of the currently identified problems/issues are currently being worked with whole or partial solutions likely within the near term. During this evolutionary period AFLC has

- Provided effective support for those ECS's for which organic software change responsibility was assigned to AFLC (i.e., F-111 and ALR-46).
- Developed an effective organic engineering capability which uses both organic and contractor resources.
- Provided implementation directives supporting AFR 800-14 such as Supplement 1 to AFR 800-14 and AFLCR 800-21.
- Developed AFLCR 400-xx, Generic Logistics Decision Tree (GLDT).
- Demonstrated the capability to organically develop/integrate sophisticated ECS support facilities such as the F-15 AISF and the EWAISF.
- Been in the forefront in developing the support concept for organically supported ECS's as evidenced by the lead role in the EW integrated reprogramming concept.
- Made major strides in organizational alignment at the ALC, ALD, and Headquarters levels to effect a better ECS support posture.
- Shown an ability to attract required engineering talent.

This is an on-going effort and many of the AFLC's areas of progress are noteworthy. Although this list of accomplishments represents only a portion of the overall success of AFLC in reacting to its changed role, the list is indicative that AFLC management is aware of the significance and impact of ECS software support. It is encouraging to note that these accomplishments were done concurrently with completing one of the most successful periods in history of providing traditional AFLC support to its users. It should be emphasized, however, that the complexity and

sophistication of ECS's have increased in recent years and currently several problems/issues prevail in providing adequate software support. The need for further improvement in technical and management efficiency to meet the demands of future ECS support is high.

It is in the light of improving and enhancing ECS support that AFLC exhibited the initiative to solicit external, unbiased assistance in examining current ECS support posture and forecasting future ECS support objectives. Thus, the requirement for an independent study effort was identified and TRW was contracted to critically examine the current AFLC ECS software support posture, to forecast future ECS support objectives, and to lay out a plan which AFLC can implement to get from its current support posture to the projected future support posture. This role differs from typical internal self-inspection roles in that the self-inspections normally examine the ALC's for adherence to procedures and regulations rather than assessing the applicability and efficiency of implemented concepts and regulations in accomplishing the software support of ECS.

1.2 REQUIREMENTS BASELINE SUMMARIES

TRW's analysis of AFLC's current ECS support posture was separated into five subtasks. Each subtask specifically examined one of the following ECS categories.

- Aircrew Training Devices (ATD)
- Automatic Test Equipment (ATE)
- Communications-Electronics (C-E)
- Electronic Warfare (EW)
- Operational Flight Programs (OFP)

The following paragraphs present a brief summary of the major findings of the analysis for each category.

1.2.1 Aircrew Training Devices

Each Aircrew Training Device (ATD) is designed to model all or part of a primary weapon system. Changes in the primary system which affect its aircrew interface may need to be modeled concurrently in the ATD. Aircrew training devices are supported at training sites under the

Development Engineering Prototype Site (DEPS) concept. A DEPS is a site where an ATD is installed and used for both training and support activities. The DEPS concept enables some organic accomplishment of ATD modifications, but introduces a dual update path (one by the ATD user and one by the ATD supporter) which is accompanied by configuration control and implementation problems. ATD support posture is adequate to allow operation of the trainers, but much of the responsibility for procedures to update or change the ATD's is vaguely defined. Specific support problems include: (1) trainers are not modified concurrently with aircraft modification, thus training experience gained on the ATD's can be obsolete for its real system capability, (2) the two paths which exist for creating changes have resulted in poor baseline control, (3) no organic capability to handle software media nor a software repository are established, (4) the DEPS and ALC communications need improvement, and (5) modifications frequently require the use of sole source contracts to the system developer due to lack of a baseline. All of these problems are addressed in greater detail in the ATD volume of this study.

1.2.2 Automatic Test Equipment

The concept for supporting Automatic Test Equipment (ATE) and using ATE for testing of weapon systems and components involves: (1) the Software Support Center for programming changes, (2) the Engineering Division for analyzing deficiencies and designing corrective changes, (3) the Maintenance Directorate for operating ATE, (4) ADPE support on an "as needed" basis from the Comptroller Directorate, and (5) an assortment of procedures and organizational relationships. Automatic testing is plagued with complexity, proliferation, and a general lack of understanding. The AFLC support for ATE is aggravated by poor quality deliveries of ATE software which means the software development must be completed within AFLC. Specific support problems are: (1) inadequate development of test program set, (2) poor UUT test program quality, (3) inadequate consideration of design for testability, (4) undefined or conflicting responsibilities, (5) poor configuration management, (6) logistics management discipline applied to engineering problems, (7) lack of documentation, and (8) poor management knowledge of ATE status. Most problems extend from a lack of planning to define the ATE required and a

lack of completing the ATE software to an acceptable and/or useable state. All of these problems are addressed in greater detail in the ATE volume of this study.

1.2.3 Communications-Electronics

Most of the systems allocated to Communications-Electronics (C-E) are large, few-of-a-kind systems. Further, the using command is sometimes either totally or partially responsible for supporting the ECS software. Thus, the total support from AFLC varies from system to system. Much of the support is contracted to the prime contractor or his alternate, especially for one-of-a-kind systems. Problems are prevalent within the C-E category because: (1) mixed user/AFLC support responsibilities dilute configuration management, (2) planning and procedural documents are neither adequate nor timely, (3) technical requirements are straining traditional management and training structures, (4) new combat support roles require increased resource planning and implementation, and (5) C-E support responsibilities are distributed among the ALC's. All of these problems are addressed in greater detail in the C-E volume of this study.

1.2.4 Electronic Warfare

The concept for supporting both ground-based and airborne Electronic Warfare (EW) systems is very similar because it uses a support station for each system but ties the systems together with some centralized support. EW systems are dynamic systems in that they are altered in response to changes in enemy threats on a near-continuous basis. This alteration necessitates a rapid reprogramming capability and a need to operate updated systems as soon as possible. Continued development of many systems has caused poor documentation or ill-defined baselines, thus configuration control is weakened. Specific areas of concern in EW are: (1) need for additional standardization from system to system, (2) incomplete software and baseline documentation, (3) lack of necessary software tools, (4) insufficient personnel with system expertise, (5) need for improved communication and analysis capability of intelligence data, and (6) more responsiveness to software changes. All of these problems are addressed in greater detail in the EW volume of this study.

1.2.5 Operational Flight Program

Operational Flight Programs (OFP's) represent the system capability of avionics in that the application of the system is described by the software. The OFP's are integral to the intent of the system and all interfaces with the system have an effect upon the results obtained by using the OFP's. In its broadest context, OFP can include EW software, C-E software, ATD software, and even a portion of ATE software. The distinction is made for OFP because of its direct relationship to weapon systems such as aircraft or missiles. The concept for supporting OFP's is an Avionics Integration Support Facility (AISF). Establishment of an AISF enables all interfaces with an avionics system or systems to be simulated or implemented so that the avionics OFP's can be exercised. Additionally, AISF's facilitate updates and/or changes to the OFP's plus some validation and verification checks of the revised OFP. Problems associated with AISF's or support of OFP's stem primarily from the complexity of the AISF's themselves. It is very difficult to initially conceive and implement a complete AISF at the outset of its establishment. Thus, AISF's are evolutionary. This is neither to say that the approach is wrong nor the overall AISF design is inadequate, for this is not the case at all. AISF's must test to a specific set of parameters in a specific scenario before meaningful technical analysis is possible. It is this level of specificity that is evolutionary. Specific problem areas noted in OFP support are: (1) the AISF concept is not uniformly implemented although most AISF's are patterned after the F-111 AISF established at Sacramento, (2) terminology and procedures are not equally implemented, (3) documentation is incomplete, causing configuration management weakness, (4) the F-4 AISF is not a full support capability, (5) support requirements are not firm, and (6) all or part of the facilities used during development are "handed down" to AFLC to use as the support equipment for avionics systems. All of these problems are addressed in greater detail in the OFP volume of this study.

1.3 ECS SUPPORT ISSUES

To assess the major issues confronting the ECS manager today, TRW convened a working group of senior engineering personnel with expertise in the support of embedded computers owned by both government

and industry. The purpose of this group was to ascertain the major issues involved in ECS support from a logistics perspective. The method of selecting the most prominent issues/drivers was the identification of a large group of alleged management problem areas that had been:

- Stated in various Air Force documents reviewed by TRW
- Related to TRW personnel by Air Force customers
- Observed by TRW personnel in the conduct of contractual tasks involving ECS

The list assimilated during the initial exercise consisted of approximately 100 purported issues. This list was reduced by eliminating items that were essentially technological issues which were then referred to another working group tasked to make a technology assessment. Another method of reducing the number of issues was the elimination of redundant issues (perceived and stated in different ways) and the consolidation of closely related issues. Issues for consideration by the working group did not include issues which were unique to an ECS category since these would be identified in the baselining activities. Items on the resulting list were then evaluated as to their:

- Definability
- Reported impact to the AFLC support posture
- Practicality of defining and implementing resolutions to the alleged issue

Each issue was given a numerical order or merit rating on each of the preceding three factors. From the preceding evaluation, 17 primary issues were identified for further study. The group collectively identified a preliminary list of key elements to be considered in the evaluation of each issue. The key elements were initially developed as areas of consideration as a means of providing a stimulus to investigate particular facets of an issue. These elements were further refined by the working group as the pertinent points of the issue became more visible. Due to the subjective nature of each issue and the fact that many of these same issues had been or were being considered by AFLC, AFALD, and ALC management, a white paper approach was taken to investigate this initial

list of issues/drivers. Each issue was assigned for investigation to a member of the working group possessing expertise in that particular area. The result of this investigation was an internal white paper which was then evaluated by all other members of the working group individually. These white papers were then iterated and finally prepared for inclusion in this volume. During the evaluation leading to the issue white papers, the primary evaluation methods were:

- Investigation of existing Air Force data such as studies, briefings, white papers, etc., related to the subject.
- Investigation of directive guidance pertaining to the particular subject.
- Interaction with Air Force ECS engineers and managers concerning their views on the particular subject.
- Solicitation of information on the subject from other TRW personnel.

During the integration of the white papers into this report, a further consolidation was made leaving the following nine subjects as the management issues with the most impact on AFLC support posture:

- ECS readiness support concept
- Personnel and training
- Microprocessors and firmware support
- AFR-800 versus AFR-300 series acquisition/support
- Configuration management
- Facility planning/funding/maintenance
- Funding
- Product/data quality at transition
- Management structure

Summarized in this volume, the TRW observations of existent needs, issues, and problems are not offered in a negative context; but simply to identify the current AFLC ECS support situation from a critical perspective.

In other words, highlight areas of inefficiency, inaccuracy, or less than adequate support. Because no single system of management or support is a perfect system, imperfections can be discovered by a knowledgeable investigation and analysis. Discernment of a problem or issue is the first step in deriving and implementing a solution. It is in this context that the following issues/problems are discussed in Sections 2 through 10 of this volume.

2. ECS READINESS SUPPORT CONCEPT

2.1 BACKGROUND

During World War II the Soviets became convinced that in order to win any future conflict, it would be necessary to control the electromagnetic environment surrounding the battlefield. As a result, beginning in early 1942 the Soviets embarked upon a combined arms concept for the employment of electronic warfare assets. From that time forward they have developed the concept and fielded the equipment necessary to combine fire power with classic electronic jamming on the battlefield. This concept is referred to as Radio Electronic Combat (REC) and has been a subject of great interest to both the Air Force and Department of Defense (DOD) over the last few years.

The Soviet REC concept targets NATO and U.S. Command and Control elements to include the:

- Controlling agency
- Communication links
- Controlled entities on board avionics (i.e., the F-15/F-16 fire control radars, IFF, navigation system and communication links; under this concept fire control radars are a high priority target

Using this targeting philosophy, the Soviets invested large resources in obtaining the lethal and non-lethal assets along with the location equipment required to degrade or destroy more than half of NATO/U.S. capabilities in this area. Of this goal, the Soviets have divided the responsibilities between lethal (firepower) and non-lethal (jamming) missions.

General J.W. Pauly, Commander of Allied Air Forces Command Europe and Commander in Chief of U.S. Air Forces in Europe, recently gave a speech before the Air Force Association. Quotations from the speech indicate just how seriously senior Air Force officials view this threat to the operational capabilities of our tactical forces. General Pauly stated,

> Since last October, we have seen evidence that they (the Warsaw Pact countries) are introducing new electronic warfare equipment – adding to the overwhelming

> capability already possessed by the Warsaw Pact. Their concept of what they call "radio electronic combat" combines electronic warfare and reconnaissance resources with firepower to limit, delay, or neutralize our use of command and control systems. They already enjoy an overwhelming advantage in the number of airborne stand-off jamming platforms and ground-based jammers. In the latter case, the ratio is 13 to 1 in their favor. Is anyone listening?†

While there have been several studies and estimates made on U.S. systems' vulnerabilities (Reference 2-1), an exact assessment of Soviet capabilities in this area is complicated by the difficulty in "collecting" actual jamming emissions. For example, unmanned collectors treat noise jamming as "noise interference" and actually remove the signal from the collector's "take". Deception jamming is even more illusive in that, in order to collect the signal, the collector must first stimulate the jammer and then remain in the jammer's field of view throughout the collection effort. Given the collection restraints, many experts in this field estimate that available documentation on Soviet EW equipment is many years behind their actual capabilities.

While the Soviets have been actively and aggressively pursuing the objectives of the REC concept, U.S. forces and most allies have increased their military capability depending upon the use of the electromagnetic spectrum. Under the direction of Secretary of State McNamara, the Department of Defense implemented the concept of "force multiplier." In almost all cases the success of a "force multiplie " weapon system is heavily dependent upon successful use of the electromagnetic spectrum; i.e., AWACS, command and control, and fire control systems of the F-15/F-16. This heavy dependency upon the use of the electromagnetic environment without an adequate understanding and appreciation for the Soviet REC has resulted in the continued development and fielding of systems which are susceptible to electronic jamming and degradation.

Not only does the REC concept advocate active interference and degradation of U.S. electronic equipment, it places equal emphasis on

†Additional insight into specific U.S. system vulnerabilities can be gleaned from Reference 2-1.

protecting Soviet command and control elements from U.S. jamming. Examples of the implementation of this aspect of REC is found in the ECCM fixes, procedures, and training of Soviet radars and radar operators. The ECCM fixes include parametric agility, low radar sidelobes, monopulse processing, wartime mode of operation, frequency diversity, radar and communication redundancy, emission security, and active training in an ECCM environment. All of these efforts have complicated the task of the U.S. ECM designer and support organizations. Nowhere was this more visually illustrated than in the Southeast Asia (SEA) conflict with the move-countermove game between the U.S. ECM designers and support organizations versus the Soviet-built SA-2 system. Throughout this "move-countermove" game it became apparent that it was impossible to react, within the time, required to a change in the SA-2 using the U.S. hardware modification approach. As a result, the use of "Embedded Computers" in the U.S. EW equipment, and their ability to be changed through software, became an accepted Air Force solution to a dynamic electromagnetic threat situation. However, ECS and their support require unique support concepts. These support concepts include availability and use of sensitive intelligence data, unique software tools, and new management initiatives. The following paragraphs will amplify on each of these areas.

2.2 INTELLIGENCE SUPPORT

The use of embedded computers in U.S. avionics, coupled with the dynamics of the electromagnetic battlefield environment, dictates a fundamental change in the historical AFLC support mission. Nowhere is this more evident than in the area of intelligence support. Figure 2-1 illustrates the problems from an airborne electronic warfare view.

This figure depicts the classic Radar Warning Receiver (RWR) and shows that, in order for the RWR to display the correct symbology, the Emitter Identification Data (EID) tables' algorithms must be developed based upon classified technical intelligence data.

Elevating this one step further, Figure 2-2 depicts the Air Force software reprogramming concept. This concept is the direct result of the Air Force's attempt to offset the classic 7- to 9-year EW equipment

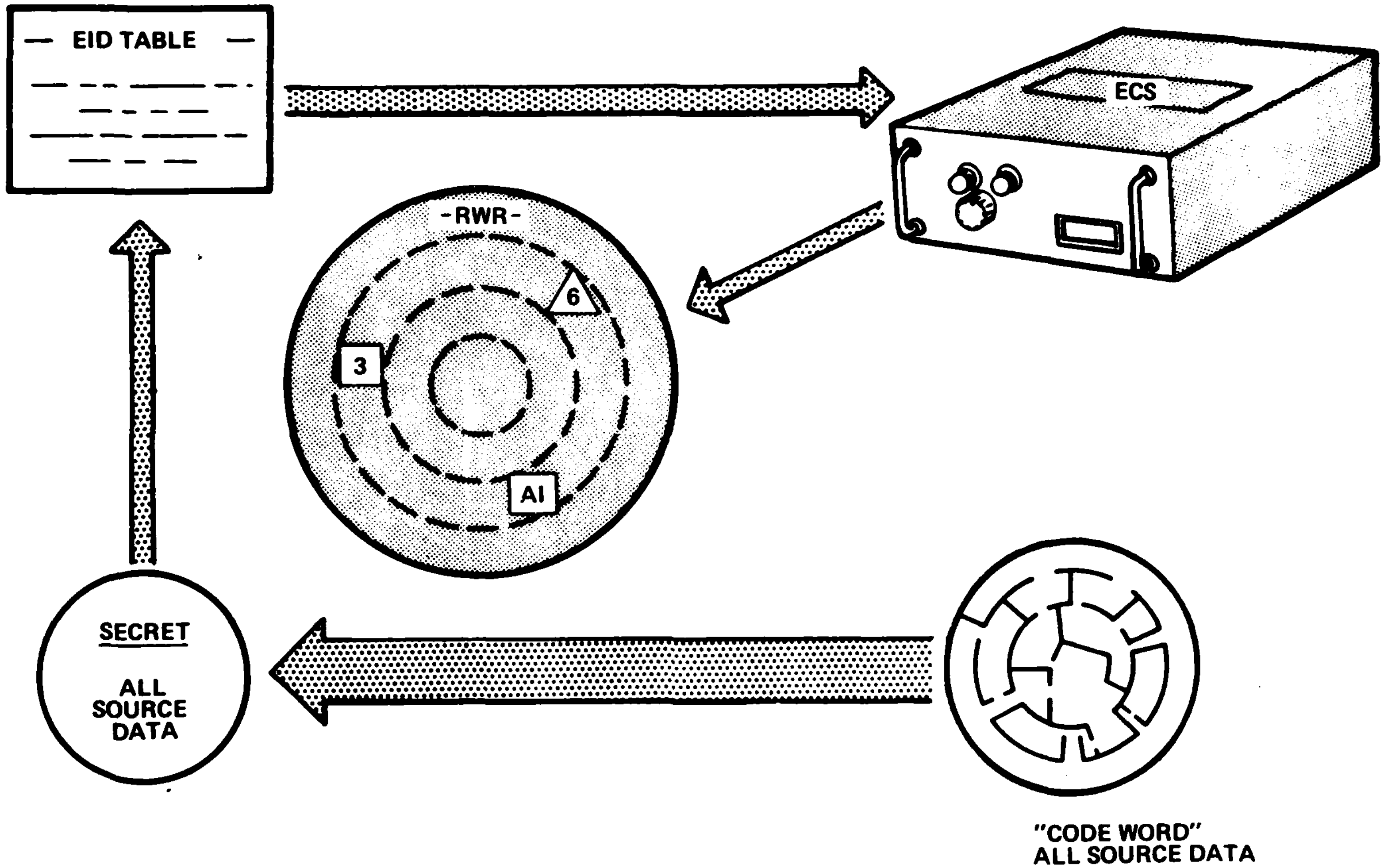

Figure 2-1. Intelligence - Engineering Data Flow

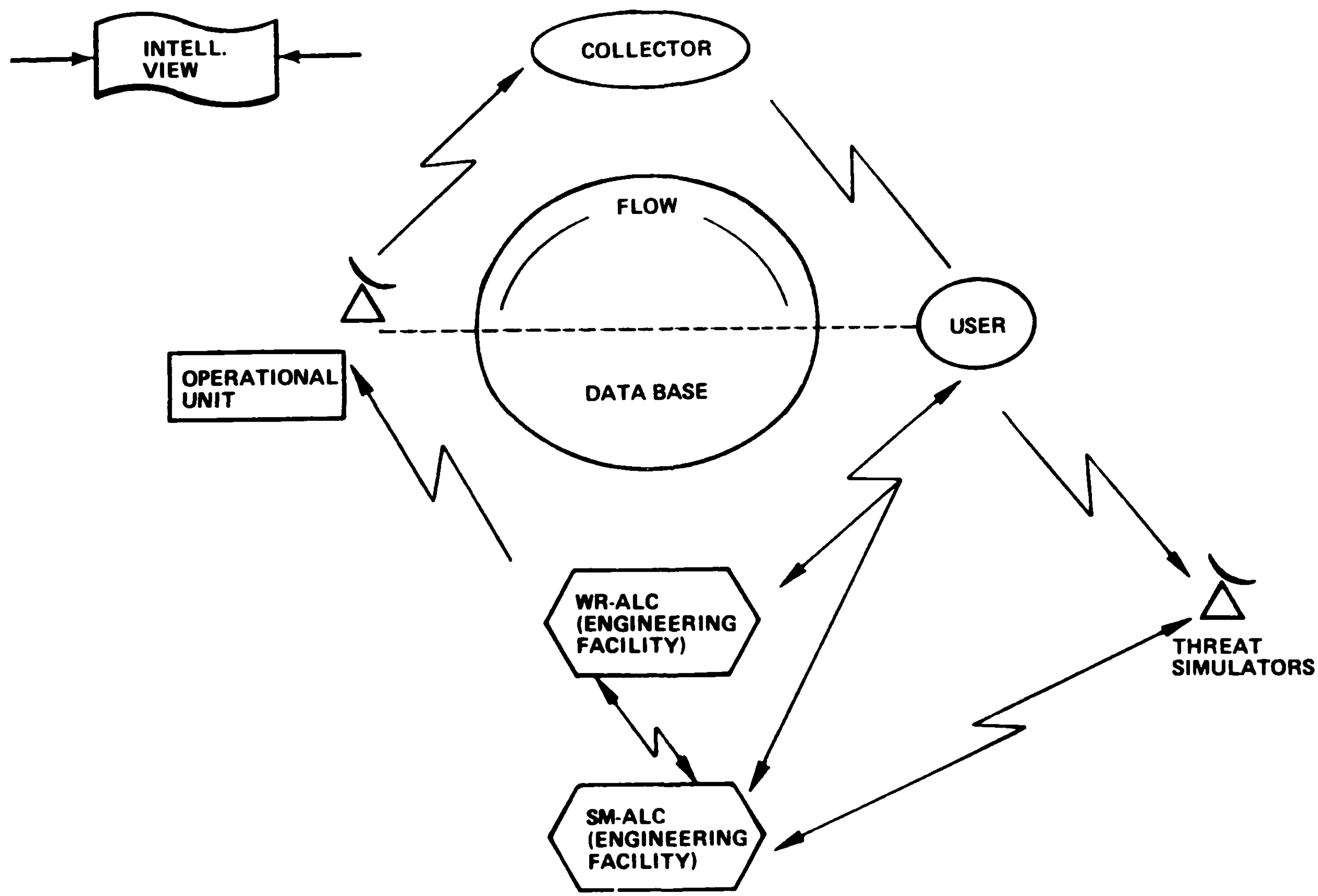

Figure 2-2. Electronic Warfare Reprogramming Concept

modification cycle through the use of embedded computers. Specifically, the concept depicts a change in the threat being detected, collected, analyzed, and distributed to the Air Force users. At this point the users, in conjunction with WR-ALC, determine the best software solution to the problem, engineer, and disseminate to the field. As depicted, the entire concept evolves around a very dynamic intelligence loop wherein both the users and WR-ALC must interact with the intelligence world. This interaction requires not only access to the data but the ability to influence the collection, analysis, and dissemination phases.

Further compounding this issue and requiring additional AFLC involvement in the intelligence cycle are the following inherent EW software support requirements:

- Preemptive Engineering Support. Currently WR-ALC, and in the immediate future SM-ALC, will be involved in assisting the users (TAC and SAC) in preemptively engineering expected EW software changes based upon predicted and highly classified technical intelligence data. Through this process the Air Force EW community is attempting to offset expected enemy wartime modes of operation and the resulting impacts these modes would have in U.S. EW equipment. More specifically, the Air Force is considering building an off-the-shelf library of software changes that can be shipped to the field and stored in anticipation of threat changes once hostilities are initiated. WR-ALC, SM-ALC, and their associated software engineers are an integral part of this Air Force process.

- Equipment Modification and Development Support. Historically, WR-ALC has been actively involved in developing the ALR-46 RWR family. Recent Air Force evaluations of these systems seriously question the ability of these systems to meet the expected threat. One of the basic reasons for this problem has been the inability of the developer to examine and evaluate highly sensitive intelligence data.[†] SM-ALC, with its emerging role to support and assist in the modification and development of U.S. ground-based EW equipment, has an equally valid need-to-know in the area. In fact, most of the newer ground-based EW equipment is designed to counter enemy command and control nets. Information on these command and control nets that is germane to the development and

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[†]Within the last few years this situation at WR-ALC has improved; however, the limited number of "cleared" ALC personnel and the availability of much of the more sensitive data still present serious problems in accomplishing the total AFLC mission.

support of the ground-based EW system, is from sensitive and highly classified SIGINT and HUMINT sources.

In the area of Airborne EW support, software support tools are under development. The Electronic Warfare Open Loop Simulation (EWOLS) and the Flight Line Test Set (FLTS) are examples. Both of these systems will require the ability to simulate large quantities of secret level parametric intelligence data. In addition, the EWOLS system will require "canned yet valid" threat scenario data. In the case of scenario data, DOD directives C-4600.3. C-3100.9, 5000.1, and 5000.2 require that all of this type data must be Defense Intelligence Agency (DIA) approved. An AF/IN 8 August 1979 letter, "Threat Assessment Development," implementing these directives, fails to recognize AFLC's role in this area; however, it points out that development of this type data is a using command's responsibility.

Equally demanding in this case is the AFLC's mission to support fire control radars, communications systems of the Seek Talk and JTIDS variety, aircrew training devices, and command and control systems such as AWACS and AABCP. Of these, support to fire control systems of the F-15/F-16 variety may be an immediate problem. As previously stated, the Soviet REC concept specifically targets fire control radars (Reference 2-2).

The vulnerability of all U.S. command, control and communications systems to the Soviet REC is of critical concern to both war planners and field commanders. To blunt the success of Soviet REC forces the DOD has directed the development of a Command, Control, and Communications Countermeasures (C^3CM) program. Specified requirements are spelled out in DOD directive 4600.4, dated 27 August 1979. The full implementation of these requirements will impact ECS in four of the support categories: OFP, EW, ATD, and C-E. The high flexibility of ECS software makes it an excellent candidate for implementing near-term countermeasures solutions. Future C^3 systems will have countermeasures capabilities designed-in during initial development. In many cases, these countermeasures features will be incorporated into the ECS software. Therefore, in addition to ECS updates for error correction and system enhancement, changes will be driven by enemy actions and counteractions

to our own REC program. As enemy REC intelligence becomes available, the ALC's must start preemptive engineering on C^3CM software updates. The timing and frequency of these updates will depend on enemy actions and the availability of the required intelligence data.

One might argue that providing such intelligence support is not an AFLC responsibility but rather an AF/IN or an FTD role. AFR 200-1 provides the overall guidance for intelligence support to the various Air Force major commands. This regulation states specifically that intelligence support is a MAJCOM responsibility, with overall policy direction provided by the ACS/I. In layman's language this means that if a MAJCOM requires intelligence support it must provide the manpower, facilities, and resources necessary from within its own structure.

Figure 2-3 is a top level look at the current impacts this new role is having on the AFLC mission. This quick appraisal shows that AFLC at both Warner Robins and Sacramento should initiate immediate actions to ascertain the resources and facilities required to support their new roles. Caution should be exercised to ensure that adequate resources and commitment are made without going too far in this respect. Accomplishment of this appraisal will require an exhaustive review of the roles of both AFLC and existing intelligence organization. The appraisal should include everything from communication requirements to facility construction. Number, location, and clearance level of personnel must be listed as an essential part of this effort.

2.3 SOFTWARE SUPPORT TOOLS

Given the dependency of our avionics systems upon the use of the electronic environment and the determination of the Soviets to deny or degrade this use, there can be little doubt that once hostilities begin much of the jamming environment to which U. S. systems will be subjected will be new and unusual. Couple this with the possible susceptibility of our avionics systems to jamming and the critical role these systems play in mission accomplishment, and one can envision a great demand being placed on AFLC/ALC to quickly modify and correct these deficiencies. Both preemptive engineering and Quick Reaction Software Capabilities (QRSC) are alternatives which should be developed. Both of these will

ALC	SUPPORT TOOLS/MISSION	TYPE DATA						CLASSIFICATION			
		PARA-METRIC	HARD-COPY	MES-SAGE	ESTI-MATE	SCE-NARIO	OTHER	SECRET	TOP SECRET	SI/SAO	OTHER
WRALC	SOFTWARE REPROGRAMMING SUPPORT	X	X	X	X			X	X		
	PREEMPTIVE ENGINEERING	X	X	X	X	X	X	X	X	X	X
	EWOLS	X	X	X	X	X	X	X	X		
	ARC										
	• NONCRISIS	X	X					X			
	• CRISIS	X	X	X	X	X	X	X	X	X	X
	FIRE CONTROL SYSTEMS (F-15/F-16)	X	X	X	X	X	X	X	X	X	
	COMPASS CALL	X	X	X	X	X	X	X	X	X	X
	EW DEVELOPMENT	X	X	X	X	X	X	X	X	X	X
SMALC	RADAR GROUND BASED SIMULATORS										
	• DAY TO DAY SUPPORT	X	X	X	X			X	X		
	• PREEMPTIVE ENGINEERING	X	X	X	X	X	X	X	X	X	X
	• DEVELOPMENT SUPPORT	X	X	X	X	X	X	X	X	X	X
	GROUND BASED EW EQUIPMENT	X	X	X	X	X	X	X	X	X (P)	X

ALC	DATA SOURCE		STORAGE		MISCELLANEOUS			PERSONNEL	
	EXTER-NAL	INTER-NAL	SAFES	VAULTS	WORK AREAS	CONF ROOM	AFSSO	SECRET T/S	SI/SAO
WRALC	X (P)		X		X	X		X	
	X	X	X	X	X	X	X	X	X
	X	X (P)	X		X	X		X	
	X (P)		X		X	X		X	
	X (P)	X	X	X	X	X	X	X	X
	X (P)	X	X	X	X	X	X	X	X
	X (P)	X	X	X	X	X	X	X	X
	X (P)	X	X	X	X	X	X	X	X
SMALC									
	X		X		X	X		X	
	X (P)	X	X	X	X	X	X	X	X
	X (P)	X	X	X	X	X	X	X	X
	X	X	X	X (P)	X	X	X	X	X

Figure 2-3. Intelligence Impacts

require development of additional software support tools. From a fire control radar view, a requirement exists to develop the tools necessary to stimulate the various systems with realistic and likely ECM techniques. Using this approach, sensitive system design areas could be monitored along with overall system performance for effectiveness and vulnerability data. Based upon this data, alternative ECCM "fixes" both in hardware and software could be either preemptively engineered or developed in real time using a QRC type approach. However, obtaining the tools alone is not the total answer. The dynamics of the electronic warfare arena forces the various Air Force communities (Intelligence, Development, Operational, and Logistical) to work hand-in-hand in order to stay abreast of the "Counter Countermeasures EW Chess Game." As a result of this "move-countermove game" preemptive engineering and QRC reactions must become a way of life in the support arena.

Preemptive engineering in this area starts with fragmented and multi-sourced intelligence data. This data reflects either adversary intentions and/or hard technical data on the various pieces of threat equipment, either in the field or in development. Using this data combined with U.S. equipment vulnerabilities and technologies, engineering estimates as to the expected adversary intentions and capabilities can be made. Based upon these estimates, countermeasures techniques and alternatives can be preemptively engineered and either installed or placed in storage for future use. To ensure community acceptance of preemptively engineered approaches and to improve the reliability of the threat estimates, a team approach involving all the key players is required. This approach necessitates that all players have access to all relevant data to include sensitive, all-source intelligence information.

From an ALC support role, even more urgent than the requirement to assist in preemptive engineering work is the necessity to develop and maintain a Quick Reaction Capability (QRC) for ECCM modification to fire control radars of the F-15/F-16 variety. As cited earlier, several high level studies have pointed out the fact that these systems are a specific target of the Soviet REC concept. As such, there will be a continuous requirement to detect, predict, evaluate, and modify these systems if they are to remain combat effective.

2.4 RECOMMENDATIONS

Initiate action to provide a stimulus and effectiveness monitoring capability for key avionics systems.† These actions should include:

- Investigation of incorporating basic stimulus and monitoring equipment as an integral part of each AISF. Should this approach be taken, an overall AFLC management oversight program should be implemented to ensure that the stimulus and the monitoring/data reduction within each AISF is standardized, that the results are transferrable, and that the intelligence data/stimulus waveforms are "valid" and universally used throughout the ALC's.

- Investigation of the feasibility of using an Electronic Warfare Open Loop Simulation (EWOLS) similar to that being developed at WR-ALC/MMR. Using this approach, the idea would be to expand the current EWOLS concept to include the capability to generate various jamming waveforms. Such a capability could be directly applicable within WR-ALC/MME, SM-ALC, and OO-ALC.

At the same time, emphasis should be placed on documenting and developing, as an integral part of the stimulus/monitoring equipment, a preemptive engineering and QRC support capability. Under this concept, the stimulus/monitoring equipment not only serves to stimulate and evaluate the baseline data/avionics system, but also allows the evaluation of changes to both the stimulus and the avionics system in a preemptive engineering and QRC development/test role.‡

Fire control radars and their associated core of trained personnel should be ranked as first priority among avionics systems to be augmented with the aforementioned support. Rationale for this ranking is based upon the following:

- These systems are currently deployed in the field. With the development of the "beyond visual range" air-to-air

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†Key systems should include, but not be limited to, terrain avoidance/terrain following radars, fire control/Nav Aid radars, IFF, and selected communications system. Particular emphasis should be given to the F-15, F-16, E-3A, F-111, and JTIDS systems.

‡Exact technical details and limitations in obtaining the capabilities discussed thus far have not been investigated. Therefore, investigation of these capabilities should be the first action taken in pursuing this area.

missiles, it is essential that these systems be capable of undegraded performance in an ECM environment.

- The numerical superiority of the Soviets in a Central European environment requires the F-15/F-16 systems be able to effectively engage with extended "beyond visual range missiles" and to do so with a high confidence kill probability on a single shot basis.

- Soviet REC is targeted against U.S. fire control radars. One of the specific objectives of this targeting approach is to deny U.S. aircraft the advantage of long range directed air-to-air missile engagements.

Train and maintain within each support facility a core of expertise in the areas described in the preceding paragraphs.

Conduct an extensive review of the current and future ALC's mission and from this, document their requirement for the use and storage of classified data to include both "Friendly/Blue" and foreign intelligence data. WR-ALC and SM-ALC should receive first priority for this review due to their extensive work in the area of electronic warfare. This should:

- Identify the type and classification of the various ALC ECS support facilities as a function of both the classified intelligence material handling/storage and the classified nature of the "Friendly/Blue" systems. This effort should include not only a review of the overall facility classification, but also identification of required work areas and conference facilities.

- Analyze and identify the type, number, and level of classification of the personnel required to support each ALC in this area.

- Document and implement appropriate HQ AFLC direction in the area of specific responsibilities for obtaining and providing the required intelligence support at the various ALC's. Specific consideration should be given to publication of an AFLC implementation regulation for AFR 200-1.

- Based upon the above work, develop a long-range plan for obtaining, storing, and working with foreign intelligence data command-wide.

In coordination with operational commands and the intelligence community, develop a concept of operations for reprogramming critical mission embedded computer systems. The EWIR concept now used for EW reprogramming should be used as a guide.

3. PERSONNEL AND TRAINING

3.1 BACKGROUND

Suffusing the personnel and training elements of computer resources are issues which should be given proper consideration in ECS support planning to ensure an AFLC ability to satisfy the capability, compatibility, interoperability, reliability, maintainability, and logistics supportability requirements dictated by the computer-laden weapon systems entering the USAF inventory in the 1980-1990 timeframe. These issues, which bear upon all levels of software Operation and Support (O&S) conduct and management, draw focus upon the ability to plan, justify, recruit, train, and retain organic personnel in sufficient number and proficiency to effectively and economically carry out the AFLC software O&S mission.

The quantity of organic personnel required to perform the AFLC software O&S job is projected to increase at an average rate of approximately 10 percent per annum through at least the next six years, to an FY 86 requirement of 3,536. This FY 86 level, almost 70 percent higher than the FY 80 requirement, will cost approximately $92 million per year based upon current year dollars. Were all ECS software O&S functions, which can be regulation (Reference 3-1) be contracted to be performed under contract to industry, more than 1,200†, organic personnel would still be required in FY 86. Mission readiness and QRC requirements [e.g., as specified in AFR 400-33, and safeguards against illegal Government-contractor employer-employee relationships as specified in Defense Acquisition Regulations (DAR) and the Federal Personnel Manual (FPM)] are expected to increase this minimal organic level by at least 100 percent. The point to be made is that AFLC must acquire and retain substantial numbers of highly skilled digital engineers over the next six years under any support concept.

Authorized manning levels significantly lag behind required manning. Approximately 2,100 personnel (Table 3-1) are required in FY 80, whereas

†Using algorithms presented in Air Launched Cruise Missile Generic Logistic Decision Tree package submitted by AFLC HQ for DOD New Start Management approval.

Table 3-1. Total ALC Projected Organic Manpower Requirements for ECS's

ALC	Manpower Requirements						
	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86
SA-ALC	181	200	218	231	245	262	282
OO-ALC	314	321	353	354	363	363	363
SM-ALC	652	863	978	1,105	1,216	1,247	1,281
WR-ALC	713	875	1,006	1,081	1,144	1,218	1,260
OC-ALC	240	310	359	350	350	350	350
TOTAL	2,100	2,569	2,914	3,121	3,318	3,440	3,536

only 1,260, or 40 percent less, are actually authorized (Table 3-2). These are distributed across MM, MA, and AC. It should be noted that this organic level is augmented by approximately $25 million of contractor engineering support in FY 80 EEIC 583 funds alone.

Table 3-2. Authorized ECS Slots, April 1980

ALC	Authorization
SA-ALC	122
OO-ALC	225
SM-ALC	303
WR-ALC	481
OC-ALC	135
TOTAL	1,266

The task of authorizing and acquiring the quantity and quality of personnel required is largely the tip of the iceberg, with training and retention difficulties being the submerged portion of the overall problem.

3.2 DISCUSSION

Illustrated in Figure 3-1 are the key elements required in developing and retaining a manpower capability for software O&S; personnel acquisition, training, and retention. Each of these elements represents a chief source of the issues which shroud the AFLC software O&S personnel and training arena.

3.2.1 Personnel Acquisition

Within the personnel acquisition process lie three interrelated areas which prompt issues. These are: (1) manpower requirements/definitions and planning, (2) the AFLC manpower justification/authorization process, and (3) recruiting.

3.2.1.1 Manpower Requirements/Definition and Planning

The issues affecting or emanating from this area are discussed in the following paragraphs.

3.2.1.1.1 Common Staffing Support Concept. The staffing software support concept used and planned for at each ALC and, by and large for

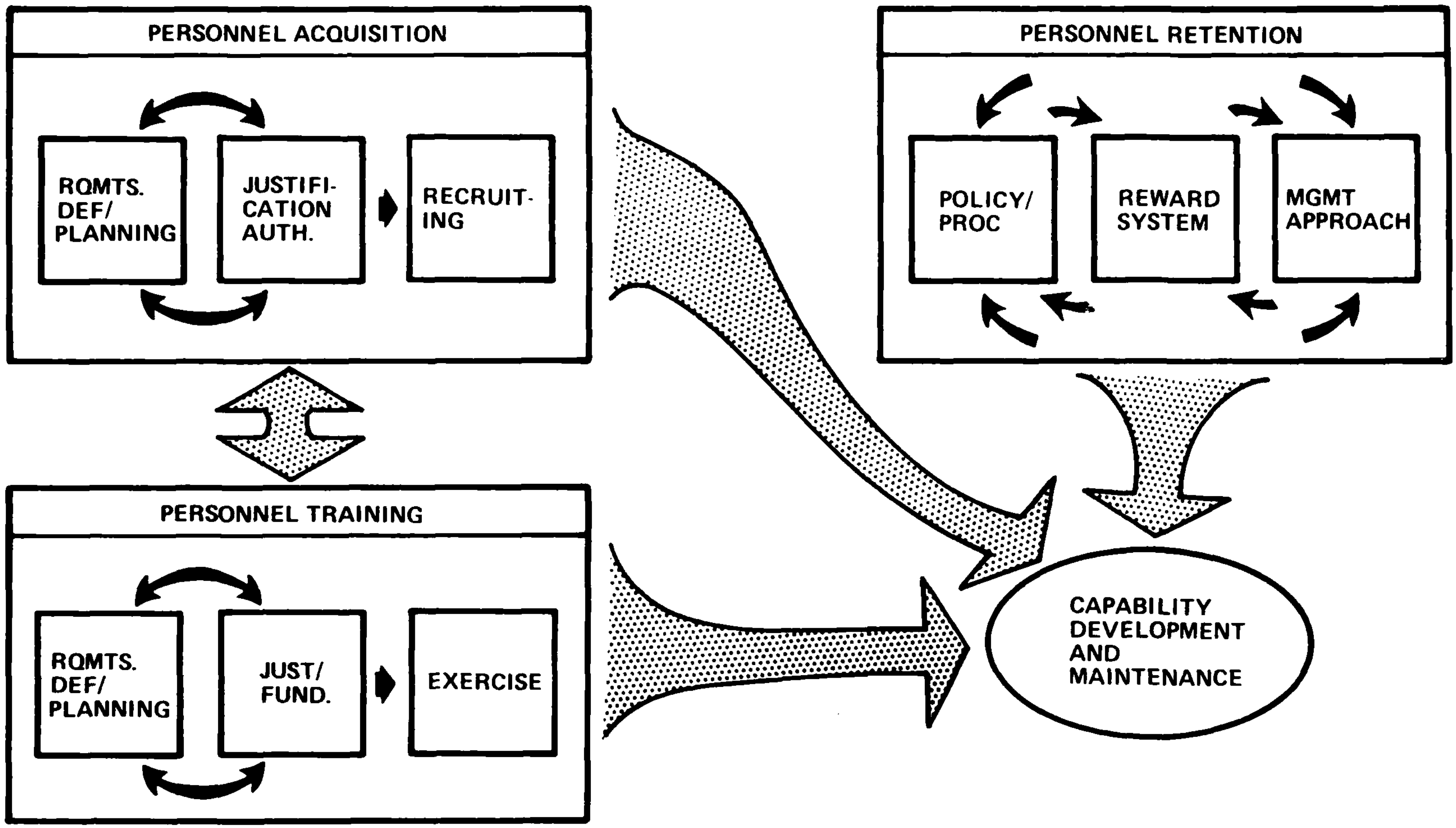


Figure 3-1. Chief Elements of O&S Capability Development and Retention

support concept used and planned for at each ALC and, by and large for each program, varies from total (100 percent) organic [e.g., E-3A at OC-ALC where 54 Government Personnel Equivalents (PE's) and no contractors are projected] to minimal Government staffing (e.g., F/FB-111 at SM-ALC, where approximately 15 Government personnel are utilized with 60 contractor PE's). Recognizing that limited manpower authorizations and funding inadequacies have largely bred such diversity, maximum use of the data extracted from these various mixes should be made to ensure that the approaches selected in the future reflect an optimum mix. Future O&S concepts should be premised upon a standard which considers the characteristics of the ECS itself, the environment in which it will be used and supported, as well as economic/readiness issues. It should be noted that OMB Circulars A-76 and 109, DODD 4100.15, AFM 400-2, AFR 400-33, AFM 26-1, AFLCR 400-XX and other guidance, while attempting to partition Government (including readiness) functions from contractable functions and Civil Service functions from military functions, leave sufficient tenuousness in their interpretation to facilitate wide mix layers.

Because of competition between agencies (user/SPO/AFLC/AFALD/ALC/interservices) for software O&S and because of SPO interests to minimize front end costs (viz. equipment, but manpower indirectly), ALC organic requirements are not always universally supported. In addition, pre-PMRT funding and manpower are not available to properly define and "sell" the AFLC support concept for a given ECS to the SPO, the user, and higher headquarters (see Section 3.2.1.1.3). As a result of these difficulties the credibility of the ALC requirements is weakened, thus diminishing the likelihood of obtaining sufficient authorization to implement the concept.

In the past, the system management support given to the software O&S posture is frequently more tacit than aggressive. This less-than-full coordination adds to the already weakened AFLC position.

3.2.1.1.2 Integrated ECR Planning. While the CRISP and O/S CMP are designed to be the chief source of integrated resource planning, both are yet to be recognized as officially approved plans to which all resource requests are linked and substantiated. Instead, each resource must be

independently requisitioned through previously existing channels, hopefully in parallel. The CRISP has thus become a "square" to be filled to avoid an IG write-up. Unless approval has been given to the MCP or AISF equipment, approval of the manpower package may be forestalled, or MCP approval may pend manpower authorization. Tendencies are to use the lack of approval of one resource as justification to deny another, creating a "chicken-and-egg" microcosm.

3.2.1.1.3 Common Manpower Requirement Baseline. Currently no single methodology for estimating manpower is recognized by AFLC. Consequently, each ALC and, by and large each program, employs a different means. This results in wide and various manning requirements across and within the ALC's which do not correlate with computer program change, size, complexity, programming language, or other characteristics which are commonly thought to affect software O&S requirements. For example, the E-3A, which in terms of equivalent instructions is approximately five times the size of and equal in complexity to the F-15 software, is planned to be supported by 30 percent fewer people than the F-15 software. Also, the EW software on three of the five USAF fighters requires more manpower to support than does the corresponding fighter OFP's. These facts lead one to believe that common criteria is needed to determine more realistic manpower requirements.

While many software studies have been conducted or are under current contract, post-deployment weapon system Embedded Computer Systems O&S has largely gone untreated; the driving interest has been in the front end (software development), rather than life cycle costs. With forecasts indicating an ever-increasing O&S cost, this emphasis should be reoriented. The software support cost study, recently completed under AFAL contract to Hughes, shows promise of providing valuable baseline data and methodology in this regard. The follow-on effort on this study, recently awarded to SCI, should provide a set of key parameters which dictates life cycle software costs.

In addition, the pre-PMRT planning for ALC manpower requirements for a given system is developed in advance of software definition and, consequently, in the absence of an in-depth assessment of the O&S job. Usually generated as part of the CRISP studies, these initial requirements

often find their way into more formally defined manpower requirements (viz., via the MES Detachment Form AF 602's, etc.). Tendencies are to freeze these requirements early, ignoring the newer O&S-peculiar data as it becomes available for fear that such a change would reflect uncertainty or a lack of knowledge, either of which would endanger chance of approval. These largely unfounded preliminary manpower requirements consequently must be lived with.

3.2.1.1.4 Common Tasking and Work Breakdown Structure (WBS). No generally accepted delineation of tasks or task structuring exists across the ALC's for software O&S. Consequently, the requirements for numbers and kinds of personnel to satisfy such a structure vary widely for what appears to be basically the same job. The ALC Computer Resources Branch (MMEC) sectional-level structure being dissimilar at each ALC erroneously suggests that each ALC Computer Resource Branch is performing a different function. The roles and functions within each ALC across MMIR, MMAR, MA-T, MMEC, and ACD organization likewise reflect little commonality. AFLCR 23-42 and 23-43 appear too general to assist in defining a common WBS. The effectiveness and efficiency offered by each WBS concept being tested should be carefully studied to arrive at an optimum approach for each type ECS supported.

3.2.1.1.5 Consistent Entry Level, Skill Level, Grade Classification. Largely as a result of having no common software O&S task definitization and WBS, as well as because of past manpower authorization ceilings, the entry level, skill level, and grade structure mix varies across the ALC's. While many of the software O&S functions can be performed by entry level personnel with limited training, certain of the engineering tasks involved in the decision process can only be performed by a well experienced cadre of personnel, adept in weapon system engineering and computer science.

ECR classifications are emerging rather than being identified. The personnel skill pool having experience in software is relatively small and camouflaged by experience crediting procedures which do not distinguish this experience from other more general skills. Local practice appears to be to classify certain software positions along the lines of the more general skills. To reach candidates of appropriate experience, "under the line" specialties (e.g., logistics management specialist/software) or

unique promotion evaluation patterns are used. Procedures addressing "applicants only" candidates are costly and difficult to manage and staff. These difficulties are greater for GS-12 and above levels because career board procedures must be followed.

Three different approaches to skill acquisition/accrual appear across the ALC's: (1) a hiring of predominately entry level electrical engineers (e.g., GS-5) and an elevation of skill level through training to target grade (e.g., GS-11) in two to three years, (2) a hiring of predominately industrially or governmentally experienced engineers (e.g., at GS-11/12 level), and (3) the cross-training of existing GS-11/12 engineers from other disciplines to computer program O&S. It should be noted that this spread in approach largely results from the ease with which staffing can be accomplished rather than by design.

The target grade mix varies across the ALC's, some having a preponderance of GS-5's and GS-7's and others are predominately GS-12's. PACER SPAN, instituted in hope of "equalizing" incongruencies in this regard, has brought about other difficulties to be discussed in Section 3.2.1.3.

With perhaps the exception of OO-ALC (which draws upon ACD support), the ALC's approach to skill development is to train electrical engineers to be software engineers. While many of the software O&S disciplines require EE background, expertise in computer science appears to be overlooked.

The common goal of these approaches should be to satisfy economically a uniform set of software O&S capability requirements (e.g., a weapon system or ECS core capability, augmented by generic capabilities in program design, coding, debugging, testing, etc.). Consequently, a blend of these approaches versus reliance upon a single approach appears most reasonable, with the selected alternative for a given situation being one which calls for the least number of personnel of the lowest skill levels deemed sufficient. The key rests in the definition of skills required.

3.2.1.1.6 Integrated Support Across ECS's. Few incentives exist for consolidating resources across systems within a given ALC, needless to say, across ALC's. Although AFR 800-14 touches upon such a goal,

the coalescing of human resources can prove to be self-defeating from an isolated ALC point of view. For example:

- Personnel and equipment costs are reduced because of the cross-utilization of resources, consequently lowering the chances of obtaining the manpower needed; vis-a-vis "the more you ask for, the more you get," push-pull logic

- Acquisition of any equipment used to satisfy the requirements for more than one system stands to be a prime suspect for 800 versus 300 series debate; it is vulnerable to a "general purpose" tag

- Disapproval of any one of the elements of a consolidated approach jeopardizes the support posture for all systems.

As a result of these shortfalls, the incentive is to require a complete, standalone capability for each system (subsystem) requiring support. Largely because of this, programmatical/weapon system management interests are usually in direct opposition to consolidation with other programs.

Aside from the more obvious economic reasons, some of the more latent benefits of cross-training personnel across ECS's and across ALC's are:

- Experienced personnel from one ECS can be utilized to assist in the start-up support of another in a temporary capacity

- Personnel from a shut-down AISF (e.g., in a wartime situation) may be used to operate another AISF still in operation

- Personnel centrally located at a given ALC may support remote off-site laboratory/field teams on a TDY basis

- With the more advanced networking tools being introduced day-to-day, problems can be resolved via real time consultations with expertise located at other ALC's

3.2.1.1.7 Contingency Planning. In ECR planning (CRISP's, ILSP's, etc.), organic personnel requirements for ALC software O&S are seldom accompanied by alternative plans to be exercised in the event that organic levels and skills cannot be obtained in the time frame necessary. Decision points or checkpoints along the way (to assess the appropriateness of initial or earlier planning) are not a standard ingredient in current

planning. Consequently, surprises arise impacting fiscal planning and requiring budgetary reprogramming.

3.2.1.2 Justification/Authorization Process

The authorization of manpower slots is a slow, tedious and sometimes fruitless process for the ALC's. No clearly discernible path exists between the many manpower justification exercises and the authorization of slots. The interface between engineering and the MES Detachment is equally murky.

Manpower requirements are submitted annually (usually more than once) in various forms and through various channels. The requirements are generally established as a result of historical information and judgment calls. How these various forms relate to each other is not clear. As they are not all focused on the same goal, different requirement levels are often reported for the same effort. Whatever the method, the requirements are difficult to defend and easily refuted. Much paper and huge amounts of time, energy, and effort are necessary to "push through" a manpower requirement which finally results in an allocation of a portion of the slots requested. In short, only subjective criteria appear to be used in the annual AFLC manpower "push-pull" exercise designed to affix slot authorizations at each ALC.

While it is not clear how additional manpower approved under the New Start (AFM 26-1)/Generic Logistic Decision Tree [AFLCR 400-XX (Draft) Task Order 78-4] process will be administered, it also seems to add a new dimension of confusion to the log jam of requirements already registered against a largely fixed AFLC manpower ceiling.

In the absence of approved manpower requirements (even though validated by the local MES Detachment), overhire positions have been used to recruit against. Overhire positions must then be "firmed up" by the reallocation of manpower reserves. As a result, some employees are brought in at entry levels under overhire/pipeline positions which can only be made firm through attrition in other areas within D/MM. While occasionally misused, this "buffer" approach to manpower buildup has proven to be a valuable alternative.

When personnel requirements are submitted and ultimately authorized, the acquisition program which generated the requirements is "down the road" and ALC engineering action requirements in support of the effort already exist in participation on Computer Resources Working Groups (CRWG's), in preparation of CRISP and O/S CMP, in PDR, CDR, test, and audit activities, etc. Thus, the more experienced personnel must attend to such actions while new people are hired and brought up to speed. Adequate training of new people may take one to three years. The experienced personnel are, therefore, in a "do the best you can" situation. This often results in either insufficient attention to the system in acquisition or neglect of already existing systems requiring support. This presents something of a paradox in that the new system must be coming along in order to justify new personnel and the personnel must be on board and trained to actively support the new system during acquisition phases.

3.2.1.3 Recruiting

The demand for experienced computer-oriented engineers and scientists far exceeds the supply today, both for industry and the government. Industry tends to pay more; it pays for potential employee visits to plants and often offers more and better benefits. Although some companies make demands on their employees (e.g., loyalty overtime without pay, etc.), the government usually is outbid in the employee marketplace. Additionally, there appears to be a degree of reluctance of some to become a civil servant. Restrictive hiring practices (grade limits, educational restrictions, etc.) further constrict the available pool. Coupling these shortfalls with the government's long and drawn out recruiting/offer authorization process results in an exceedingly slow, if not insurmountable, organic manpower buildup. Some fine efforts to glamorize the organic role through marketing (e.g., brochures and nationwide advertisement) have paid off in acquiring some of the lesser skills required. While most of the ALC's have been successful in acquiring personnel in the quantity necessary, their success at acquiring the more experienced, energetic software engineer varies, depending upon the labor pool from which they are selected.

Considering that generally the ALC's do not have a recognized recruiting activity per se, and in the absence of integrated recruiting plans, the ALC's have done remarkably well in acquiring personnel.

3.2.2 Training

Upon being authorized manpower slots, the government organization is expected to immediately fill them with highly qualified and experienced individuals who begin at once to produce. Unfortunately, even when the government is able to induce well qualified individuals with some experience into joining the fold, an orientation and learning process of up to a year or more is necessary before these personnel are fully acquainted with the government's specific systems and software and with the Air Force way. When such a position is filled with entry level personnel, the process takes from three to five years. The training/learning process consists of working with journeyman level and lead engineers, general on-the-job training, service schools, and formal courses through Air Training Command (ATC).

3.2.2.1 Training Source Selection

Finding acceptable training sources for specific systems/software and funding for training are delaying factors, and the time consumed in arranging for and obtaining such training stretches the learning period into a long term effort.

Often only a contractor involved in the development of the software is in a position to provide adequate training to those who must support it. Frequently, it is found that the contractor has not recognized such a training requirement to prepare for it in that his knowledgeable personnel are dedicated to design and development efforts and cannot be released to prepare for and conduct training programs. This results in the contractor (if he responds at all) attempting to bring some of his other personnel up-to-speed hurriedly and in a rather catch-as-catch-can manner so that these people can conduct the training. The acceptability of this depends upon various factors such as qualifications and teaching ability of the selected instructors, the complexity of the subject, and how much they are able to absorb within the time frame permitted. Another difficulty in this area arises when contractors respond with no-bids or limited

proposals because of proprietary implications involving the software or its documentation or, in some instances, software design or troubleshooting aids and company methods and support tools.

3.2.2.2 Firm Training Plans

A lion's share of AFLC training problems appears to be brought about by an absence of firm training plans/procedures, combined with recurring delays in establishing any kind of reasonably credible training schedule. For example, on E-3A requests for software training were forwarded to ATC as early as 1975. A 13-week general lead-in course was derived and is repeatedly taught by ATC personnel so that all personnel can take advantage of it as a prerequisite to individual courses on each specific piece of software. A short course for E-3A software management personnel was contracted to Boeing and was taught by Boeing in first quarter 1978 on the system maintenance computer program fault trees. Formal training for the radar software, diagnostic and pre-mission readiness software, microcode, 4PI hardware, and navigational-guidance software is yet to be scheduled.

Planning for other actions to fit around the training is difficult to accomplish. The formal training unknowns often detract from efforts to procure contractor services in other areas because of a fear of conflict in schedules. Uncertainties in the training planning are not only a matter of when, but of whether it will take place at all.

3.2.2.3 Training Funds

Overall Air Force training funds projections (including TDY) seem to either be underestimated or are drastically cut in the face of funds austerity. Thus, ATC defers much training to a following fiscal year. Slippages then accumulate as new requirements each year add to past year deferred training, creating a compounding set of unsatisfied training requirements.

3.2.2.4 Training Schedules

Scheduling training is a problem area not only from the funds/instructor availability standpoint, but from an overall program synchronization point of view. First, personnel must be available to train; secondly.

equipment and systems must be available for practice exercises outside of the classroom desktop environment; and thirdly, an attempt must be made to define a schedule which will not incur unacceptable training overlaps (since personnel are sometimes cross-trained in more than a single computer program) and which will fit in with informal OJT and with other required activities (such as design reviews and audits, technical interchange meetings, participation in test efforts, etc.).

3.2.3 Personnel Retention

The government has historically retained many career people who spend their working lives from start to finish in the civil service ranks. Recent indications show, however, that such is not the case for activities within the computer arena. On the contrary, the trend in this area appears to be a training ground for junior engineers who leave for greener pastures just as they reach a truly productive stage. The lack of promotional opportunities, non-competitive salaries, job dissatisfaction, and insufficient opportunity for professional development are generally given as major reasons for engineers voluntarily leaving. Software engineers characteristically like to become involved in laboratory functions, to get into design and prototype, not to be bothered with administrative procedures, to avoid red tape and paperwork, and to have ready access to equipment, parts, materials, literature and so on. Government service, viz. in AFLC, tends to pay less, require more paperwork, levy restrictions and red tape in obtaining work materials, and frustrate every endeavor to accomplish something. More often than not, it seems that a continuing series of restudies and rejustifications is required. While these frustrating situations occur in industry, they appear to be less visible and have less impact on the journeyman level engineers. Consequently, large numbers of government people depart in hopes of better pay and fewer frustrations.

3.2.3.1 Red Tape

The government red tape involved in conducting everyday business (cost, activity, time, travel accounting, reiterative justification for slots, conformity reporting, etc.) significantly reduces the amount of productive engineering time. The actual time spent complying with this red tape is augmented by the accompanying effects of continual interference and frustration.

3.2.3.2 Promotion

Target grade limitations, combined with the government's more rigid GS growth structure/candidate selection process gives rise to having unqualified (i.e., inexperienced in software/ECS's) personnel managing and performing O&S tasks. The frustration of not being promoted when true merits dictate, combined with the futility of reporting through the resultant structure, serves a demoralizing blow to the aggressive software engineer/manager.

3.2.3.3 Responsibility/Authority

Because of the service capacity in which the computer resource branches are ordained, their role is sometimes marked with responsibility without commensurate authority. Particularly in the pre-PMRT domain when TDY funds and support personnel are scarce, the MMEC software engineer must negotiate with the SPO, user, AFALD, and other ALC's in attempting to establish a software O&S posture, often without the full backing of the SM.

As AFALD is the AFLC prime mover in the pre-PMRT era, the ALC representative must assume a back seat role. In cases wherein AFALD is not quite as strong as it should be, this can prove to be a demoralizing venture.

3.2.3.4 Professionalism

To ensure accountability to the multitude of agencies and activities created to ensure that government employees are not taking advantage of the system, rigid and sometimes degrading measures are taken to control such things as working hours, TDY benefits, administrative leave, and comp time.

3.2.2.5 Technical Challenge

As a result of manpower shortages, delayed training, etc., the junior (or untrained senior) engineer finds himself in the unpleasant situation of having to make vital decisions (or provide vital inputs) without the benefit of technically understanding the issues at hand. On the other hand, the bright, conscientious engineers are not satisfied with a "paper work" job forced upon them by delays in equipment deliveries. Numerous

resignations from civil service give "lack of challenge" as the reason. With the amount and quality of work now required by AFLC, good planning and resource utilization can alleviate any lack of challenge.

3.3 RECOMMENDATIONS

Many of the aforementioned issues are not peculiar to AFLC but rather common with those confronting other government agencies and, in cases, industry engaged in software development and O&S. Tempered with the recognition that these issues largely represent the bow wave of a rapidly expanding technology and that such issues are by no means new to USAF management, this points to their tenacious nature. The alternatives tendered below, together with other DOD and USAF efforts currently underway to address such issues, however, offer the promise of eventual resolution.

1. Develop within guidance provided by HQ AFLC (e.g., via AFLCR 800-21, AFLCR 400-XX)

   a. Detailing of the various support concepts and alternatives, and accompanying decision rationale, requisite in arriving at an optimum approach (i.e., a more detailed version of the logic paths sketched for the AFLC GLDT in AFLCR 400-XX). Included should be a clear breakout of governmental and readiness functions. It is recommended that any organic staffing logic used be based upon an average employee tenure of 4 to 7 years versus the 15 to 20 years usually associated with government employees.

   b. Specific guidance/AFLC policy regarding the consolidation of resources (including cross-training) across ALC's and ECS's.

   c. A generic breakout of functions and activities required in the software O&S job for a given ECS as well as for a multi-ECS environment (Reference 3-1 provides the rudiments for such a breakout).

   d. A skill level index accompanying position descriptions, and manpower quantity algorithms which tracks with 1a through 1c.

   e. A step-by-step, time-phased trace depicting the manpower acquisition (authorization) process, including new starts and other additive elements, as well as a responsibility breakdown between HQ AFLC offices, ALC offices, and MES Detachments. Other manpower exercises which are conducted but not related to the

authorization process should be discussed for information purposes.

f. An expansion of the CRISP content to include contingency planning for ECR's in the event manpower, funding, MCP's inherent in the primary support role are delayed or denied.

2. Conduct a study to evaluate traditional support roles and missions of the various AFLC organizations (i.e., AC, MMR MMEC, MMET MA-T) as they relate to computer resources, including the matrix management concept in the ALC's. The result of this study should be a work breakdown structure for the job description in 1b.

3. Clarify and definitize in USAF-level guidance (e.g., AFR 800-14) the roles and missions of the using command and support command insofar as software O&S is concerned. The guidance should be well keyed to the concepts and alternatives developed in 1a.

4. On the basis of the WBS developed in 2, provide guidance to the ALC for organizational structure in MMEC organization and definition of interface functions within the MMR, MA-T, AC, etc., organizations.

5. Establish through channels a means to provide sufficient pre-PMRT manpower and funding for post-deployment posturing, DT&E, IOT&E support, etc.

6. Establish a recruiting activity within each ALC, thus reducing the engineering role in this regard to one of conducting technical interview and deciding among candidates. Make provisions as necessary for manpower requirements for activity and funds for TDY, advertising, etc.

7. Replace the MES Detachment function in the software O&S manpower authorization loop by establishing a manpower screening function within HQ AFLC/LOEC to approve ALC software O&S ECR requirements.

8. Take steps to have software manpower removed from the "additive" category and placed in the manpower baseline with other O&M functions.

9. Take action through HQ USAF to establish CRISP's as formal intercommand MOA's and formal instruments of approval for ECR's.

10. Continue attempts to establish special categories and high grade authorizations for software engineers (via the Joint Civilian Personnel Management Group studying recruitment, retention and utilization of engineers and the Civil Service Commission).

11. Establish Offices of Primary Responsibility (OPR's) for ECS software O&S's training at HQ AFLC/LOEC and at each ALC.

12. Develop a top level training plan, in coordination with ATC, AFIT etc., for ECS O&S engineers and managers. The plan developed in 1976 by HQ AFLC/LOEC represented a good start in this regard. It is strongly urged that a one-year to 18-month formal training program (such as currently conducted for flight training, maintenance officer's school, logistics management school, etc.) be developed for software engineers and a two- to four-week course for software managers.

13. Establish in HQ AFLC/LOEC a special position (e.g., GS-14 or GS-15) for an expert in ECS O&S who has first-hand experience in the problems confronted by ALC's. This position, which might be rotational in nature, should be filled from the ALC's. The chief role of this position would be to advise the ALC's of their problems and to participate in the HQ decision process.

14. Explore more effective means of using the networks available to AFLC for training and cross-training devices.

15. Within the WBS developed in 2, consider adding additional administrative positions for absorbing many of the less technical functions now carried out by the software engineers.

16. Encourage rotation of key personnel across ECS's (and even ALC's) to help in keeping these invaluable resources challenged as well as to accelerate the training process for the more junior employees.

17. Establish a more structured communications loop between HQ and the ALC's through in-house status/problem reviews.

4. MICROPROCESSORS AND FIRMWARE

4.1 BACKGROUND

Microprocessors and firmware have begun and will continue to have a major impact on AFLC support and management of electronic systems. Because of the many advantages provided by microprocessors and firmware, such as flexibility, reliability, economy, and variety, proliferation of devices and their increased use appears inevitable. Mass production techniques have reduced the size, cost, and power of Large Scale Integrated (LSI) circuits and promise to usher in the Very Large Scale Integrated (VLSI) circuits with greater gate density, more gates per package, lower cost per gate, and lower speed-power product. While this evolution of technology appears staggering at first observation, the ultimate task of the AFLC avionics engineer (to enhance/correct mission-related logic in systems/subsystems) has not changed. Only the implementation methodology and tools utilized have changed in some cases. Also, the trend in resource allocations is changing to the point that hardware costs are a less significant percentage of the total cost of system/subsystem development and subsequent modifications. The technology evolution is more manifest in the greater range of applications that are now practical to implement through LSI and VLSI technology. The objective of this section is to develop the rationale for a comprehensive support posture within AFLC which will encompass this expanding technology. The impact of management stems from the requirement to plan, budget, and staff to support the unique qualities of these devices. The most important observation made during this investigation was the need for common treatment of microprocessors and firmware by AFSC and AFLC.

4.2 DISCUSSION

Microprocessors and firmware have accelerated the changing role of AFLC by providing both change flexibility to previously hardwired circuits within airborne systems and a means to accomplish support tasks that previously were impossible to accomplish or were accomplished manually. The speed and size available with state-of-the-art devices make it possible to provide signal processing capabilities that lend themselves to real time applications in the area of programmable interfaces

and switching networks within support facilities, as well as airborne instrumentation/equipment. The costs involved with this technology now make it economically feasible to support activities previously accomplished manually, from improving automation of man-machine interfaces to off-line text editing. The rush to the proverbial computer-on-a-chip concept has tended to confuse the issue of computer acquisition, management, and accounting. The requirements for these devices contradict the procedures established under the AFR-300 series regulations dealing with automatic data processing equipment; however, they possess characteristics of computers that impose a support concept different from non-reprogrammable circuits.

Technical impacts are significant. More processing capability provides for higher data rates, which in turn dictates higher speed data handling capabilities. On the positive side, these higher processing capabilities provide more and better data for avionics usage or engineering analysis, assuming that the capability exists to assess and utilize the data. Management impacts are driven by the technical issues, in that management must assume a posture responsive to these newly-acquired support requirements.

Another impact on management is the management data that will be available in real time. For example, within today's technology access to a data net containing management information can be made available at the manager's desk, in real time, that heretofore was passed to him in monthly reports. While such capabilities for management and administrative functions are now considered commonplace, their full potential has yet to be realized.

One method of discussing the support requirements, and thus management considerations for microprocessors and firmware, is to make the distinction between standard software support for general purpose computers and the attributes of microprocessors and firmware that make their support different. These differences may be categorized in the following general topics:

- Definitions
- Configuration management
- Support tools

- Languages
- Logistics considerations
- Data requirements

4.2.1 Definitions

Because of the wide variety and diversity of devices available in the marketplace (currently approaching 200) and the multitude of applications employing these devices, a universally accepted standard set of definitions does not exist, or rather, there are several sets of standard definitions cited, depending on the author being read. The following set of definitions and alternatives are stated in the ASD Airborne Systems Software Acquisition Engineering Guidebook for Microprocessors and Firmware:

- Microprocessors. "One or more Large Scale Integration (LSI) devices that, when interconnected, perform the function of a Central Processing Unit (CPU)." (AFR 800-14, Vol. I/AFSC Supplement 1, 8 August 1977, Att. 1, paragraph 14.2). Large scale integration is defined in paragraph 14.8 of the above as "complexity greater than approximately 1000 logic gates." This is preferable to MIL-STD-HDBK 217B which defines it as 100 gates or greater. A current draft of Electronic Industries Association (EIA) definitions describes a microprocessor as "a single integrated circuit which determines and implements at least the arithmetic logic unit, control function, and instruction-set architecture of a computer."

- Microcomputer. "A microprocessor plus other components, such as memories, clocks, and various interface devices that collectively operate as a stored program computer." (op. cit., paragraph 14.3). A simpler definition is a computer whose CPU is a microprocessor. Microcomputers may come packaged on a single chip or set of chips, and often are sold as a preconfigured card or set of cards.

- Firmware. The term firmware is used for two different concepts which must be distinguished. The first is, "Computer programs and computer data at the microprogram level." (op. cit., paragraph 14.5). This type of firmware is concerned primarily with computer design and instruction set definition and implementation. It is not within the purview of this guidebook and will not be considered further. The second is, "Any level of executable computer programs and computer data that cannot be readily modified under program control, that is, read-only" (Ibid.); "Software that resides in a non-volatile medium which is read-only in nature. Firmware is completely write-protected when

functioning in its operational mode." (AFR 122-10, 27 November 1978, Att. 1, paragraph 20).

The following set of definitions has been recommended as changes to AFR 800-14, Vol. I/AFSC Sup I by Dr. R. J. Sylvester, ASD/EN in his white paper on AFSC microprocessor policy:

- Computer equipment. Devices capable of accepting or storing computer data, executing a systematic sequence of operations on computer data or producing outputs.

- Instruction set architecture. The attributes of a digital computer as seen by a machine language programmer; i.e., the conceptual structure and functional behavior of a digital computer (at the machine language level) as distinct from the organization of data flows, logic design, and physical implementation.

- Microprocessor. A single or small set of integrated circuits which implement at least the arithmetic logic function, control function, and instruction set architecture of a digital computer.

- Microcomputer. Microprocessor(s) plus the necessary support devices (if not already part of the microprocessor) which implement a digital computer. (NOTE: A computer-on-a-chip is considered both a microprocessor and a microcomputer.)

- Firmware. Any level of computer programs and/or computer data that cannot be readily modified under computer program control; that is, read-only. The definition also applies to read-only digital data that may be used by electronic devices other than digital computers.

- Computer data. Basic elements of information used by digital computer equipment in responding to a computer program. Data operated on, produced by, or otherwise used by a computer program.

- Integrated circuit. An electronic device, commonly called a chip, that integrates individual electronic elements (i.e., transistors, diodes, resistors, and capacitors) onto a single solid-state substrate.

- Large scale integration. Any integrated circuit chip with a complexity greater than approximately 1,000 logic gates.

- Embedded computer. A computer that is integral to a larger system, subsystem or component from a design, procurement, and/or operations perspective. The larger system function is not generally data processing.

- Hardware intensive applications. Those embedded computer applications in which the function is fixed and hence the computer program (after development and test) is not expected to be changed for the lifetime of the physical component in which the computer is embedded.

The latter set of definitions is more inclusive in scope by attempting to provide definitions of computer equipment, instruction set architecture, computer data, and embedded computer that encompasses the field of microprocessors. However, the white paper definition for microprocessor does not include larger aggregations of chips such as in bit-slice applications. In both references, AFSC has attempted to define subsets of device applications which are Hardware Intensive, Software Intensive, and Firmware Intensive allowing classification based on logistic support requirements rather than commercial device configuration. AFLC has a set of definitions in AFLCR 800-21, Attachment 1, which differs from either of these slightly. It also addresses hardware and software intensive applications. While it is recognized that the support required is heavily dependent on application, it must also be recognized that this classification is somewhat subjective and must be made early in the system/subsystem development process to accurately assess the support requirements. That is, to classify the application accurately requires technological decisions based on system knowledge and operational requirements. This assessment cannot be taken lightly and must be accomplished by extremely knowledgeable personnel. Since the policies and methodology used by AFSC in dealing with microprocessors and firmware will have a major impact on the AFLC support posture, it would appear to be a tremendous advantage to have a mutually agreed upon and used set of definitions and criteria from which to work so that transition can occur with as little confusion as possible.

4.2.2 Configuration Management

The unique properties of microprocessors and firmware dictate unique configuration management procedures different from both hardware and software yet encompassing techniques from both. It is obvious that a baseline must be established and configuration and status accounting maintained; however, the detailed implementation of a standardized universal system is made more difficult by the physical and electrical

properties of the varied devices. For example, firmware when programmed may have an almost unlimited number of possible configurations which are machine readable, but which require specialized equipment. Combine this with the fact that both the program and the media embodying the program must be controlled. A "reasonable" example of identification for configuration control extracted from requirements of DI-A-3001 is provided in the ASD microprocessors and firmware guidebook as:

Media and Related Documentation

- CPIN
- Version/distribution date
- Chip number-of-total
- Socket number
- Additional data as required (e.g., inventory number, internal check sum)

External Identification

- Vendor part number
- Version number
- Socket number

Internal Identification

- Same as media and external identification
- Additional, if required

The external/internal identification scheme suggested in the guidebook is presented in Figure 4-1, with the internal identification encoded in source test format near the beginning of the chip, if possible. In addition to the special identification requirements stated above, the program must be managed as a system element as dictated by AFR 800-14 under MIL-STD procedures. Data and documentation requirements are cited in another paragraph because of the physical characteristics of the chips themselves and the boards on which they reside. Labeling to identify the media and the internal configuration of chip and/or board is complicated.

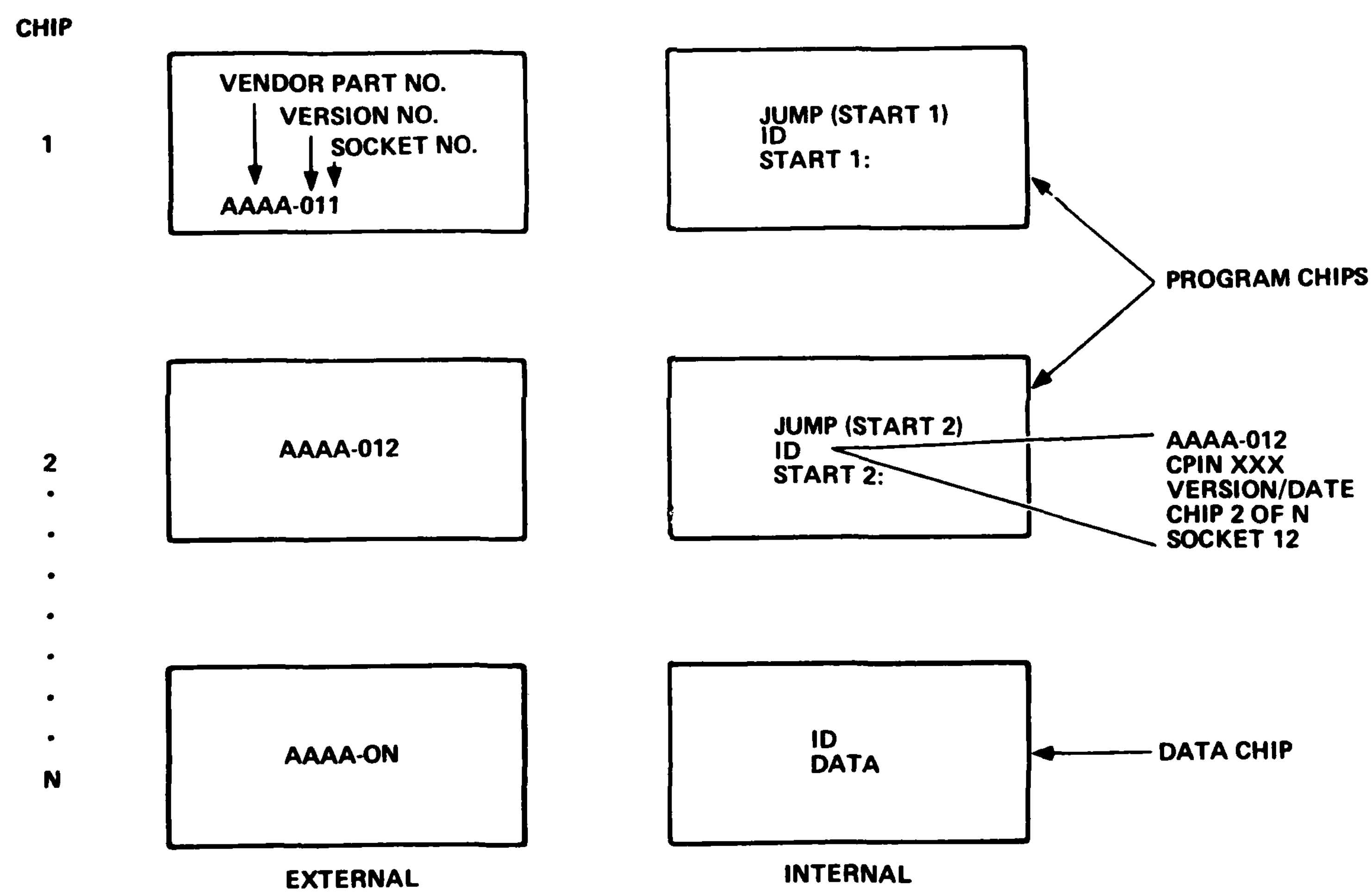


Figure 4-1. Firmware Device Identification

A standard method of identification and labeling for the chip, board, and black box is needed.

4.2.3 Support Tools

One of the major impacts on AFLC perpetrated by the evolution of microprocessors is the requirement for additional tools to develop, test, and modify logic implemented via chip technology. These tools span the range from universal microprocessor development systems commercially available from various vendors to specially designed software test aids unique to one particular chip. Paragraph 4.2.3.1 is a discussion of commonly used tools extracted from the ASD microprocessors and firmware guidebook. While many of these tools are commercially available and may be applicable to multiple chips and uses, normally a great deal of engineering labor is required to develop application and device/system-peculiar support attributes. Even with these labor-intensive efforts considered, an excellent microprocessor laboratory facility can be acquired for relatively low cost due, for the most part, to the inexpensive nature of the hardware involved.

The development of standard support facilities at the five ALC's and AGMC could have the effect of bringing some commonality to this support arena and pressure the acquisition agencies into restraining the proliferation of devices more to those for which a support capability exists. While there are implications in some of the recent documents that AFLC is considering the acquisition of a standard microprocessor support facility, the only efforts apparent are system/application-peculiar acquisitions, along with the planned development system at McClellan. It appears that a centralized effort to procure and integrate a standard growth-oriented laboratory for all the ALC's is needed to meet current and future needs.

4.2.3.1 Tools and Techniques for Microprocessor Development and Support

Although microprocessor systems are conceptually divided into hardware, firmware, and software subsystems, functionally they operate as a digital system. Implementing a given subsystem in firmware or software rather than hardware buys you increased flexibility but only if appropriate tools exist to capitalize on it.

The purpose of a tool is to:

- Provide visibility into system operation
- Automate repetitive control tasks
- Collect a d reduce data on system behavior

No automated tool known can prove program correctness. Hence the best tool will provide controlled exercise of the microprocessor with the maximum visibility, speed, and ease of use, and collect and reduce the most behavioral data for ultimate human analysis.

4.2.3.1.1 Types. Tools unique to microprocessors and firmware are presented below.

- In-Circuit Emulator (ICE). A device which is substituted in place of a microprocessor and which duplicates its operation both logically and electrically. Usually operated in a master/slave relationship in conjunction with an MDS microprocessor acting as master: plugging the slave microprocessor (ICE) in place of the target microprocessor extends the capabilities of a MDS to those of powerful Computer Monitor and Control (CMAC). A memory-mapping capability allows the target microprocessor to utilize MDS memory as if it were its own. In addition to substituting for the target microprocessor and interfacing to the MDS, the ICE usually contains trace buffers and other diagnostic aids. An ICE may also come as a self-contained system packaged in an attache case for field use. This is a device that is unique to LSI technology and has almost unlimited utility.

- Logic analyzer. A device for monitoring other digital devices on the logical level. Displays timing information and logic levels. Displays numerical data in a variety of formats, including as disassembled machine instructions.

- Memory mapping. Substituting one memory for another via a real time address translation map.

- Microcomputer Development System (MDS) or Microcomputer Prototyping System (MPS). A microcomputer configured as a stand-alone system for software/firmware development and support. Besides the features of minicomputer systems (mass memory, operating systems, CRT's), it has the capability of interfacing with a PROM programmer (or other firmware configuration tool), and an In-Circuit Emulator (ICE) or other microprocessor debug tool. The mass memory device may consist of anything from paper tape to disc, usually floppy disc (diskettes).

Lack of capability to support multiple users may be a problem.

- Microprocessor analyzer. Similar in capabilities to an ICE, but clipped onto the microprocessor leads instead of substituted for the microprocessor.

- PROM programmer. A tool for imprinting (programming) and reading the bit patterns of Programmable Read-Only Memory. May be operated remotely by an MDS, or manually. Can also be used to verify the contents of PROM's.

- ROM simulator. A writable RAM used to emulate a ROM to enhance firmware debug prior to burn-in. May be purchased separately or as capability in an ICE.

- Signature analysis. A method for isolating faults to the node level in a logical circuit. Requires additional circuitry built into the system.

- Trace buffer. A memory for the storage of real time microcomputer bus signals for use in logic testing. Usually runs under control of an MDS in conjunction with an ICE.

- Universal development system. An MDS with capability of multiprocessor support, including interface with multiple ICE's.

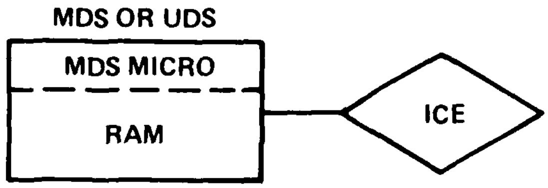
4.2.3.1.2 Use. The MDS with an ICE, logic analyzer, and a PROM programmer is currently the most effective combination known for microprocessor life cycle support. The Universal Development System (UDS) has the further attractive capability of supporting, with appropriate adapters, multiple dissimilar microprocessor types. Their use in the life cycle is briefly described as follows.†

† Logic analyzers are useful for hardware debugging throughout this cycle, especially in areas of timing, and parts of the circuit relatively invisible to the microprocessor.

- Development Test and Evaluation Phase

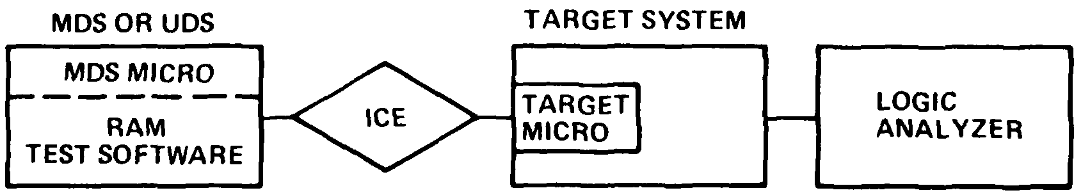
A. The MDS (or UDS) may be used in advance of hardware development to code and test all internal microprocessor routines.† The use of the ICE allows emulation of the stand alone microprocessor and symbolic debug of the program. No firmware memories need to be used at this stage, as the MDS RAM will emulate them through the memory-mapping feature.

STAND ALONE DEVELOPMENT OF SOFTWARE



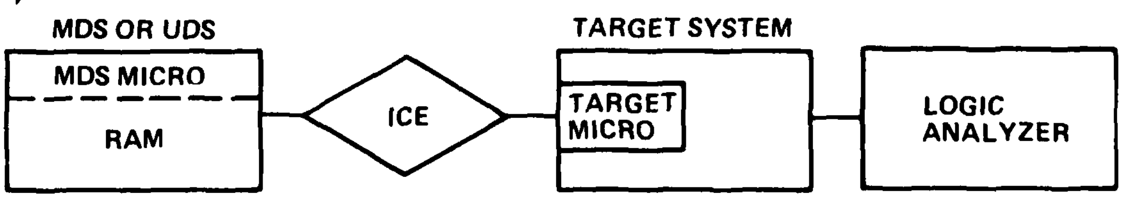
B. Effective use may also be made of a MDS/ICE to debug microprocessor hardware by executing software diagnostics and I/O drivers.

DEBUG OF TARGET SYSTEM HARDWARE



C. Then the software may be exercised under MDS control using the ICE in the final circuit environment of the microprocessor. At this point the MDS RAM (using the memory-mapping feature of the ICE) is still used to emulate the target PROM or ROM.

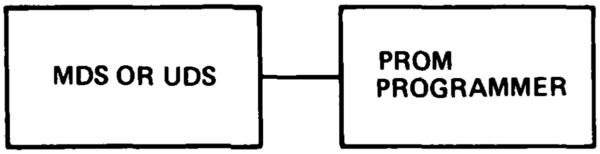
DEBUG OF TARGET SYSTEM EMULATED FIRMWARE



†Cross-compilers and assemblers may also be used at this stage.

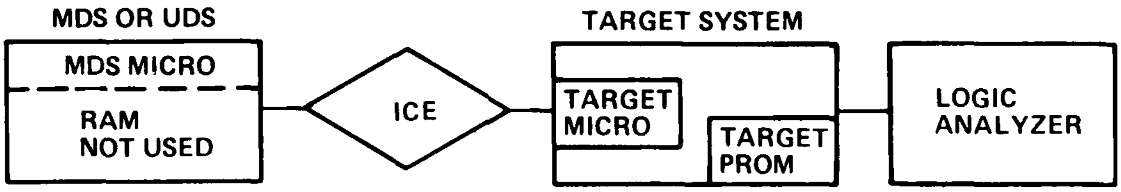
D. Next, the PROM may be imprinted using the PROM Programmer under control of the MDS.

BURN-IN OF FIRMWARE



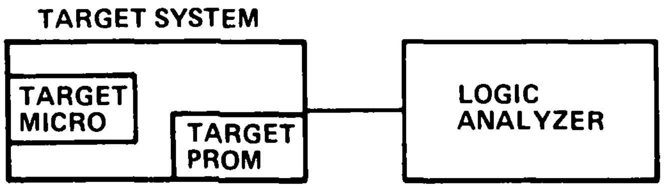
E. Now the PROM's may be plugged into the target system, and the code executed using the ICE under control of the MDS.

DEBUG OF TARGET SYSTEM WITH FIRMWARE IN PLACE



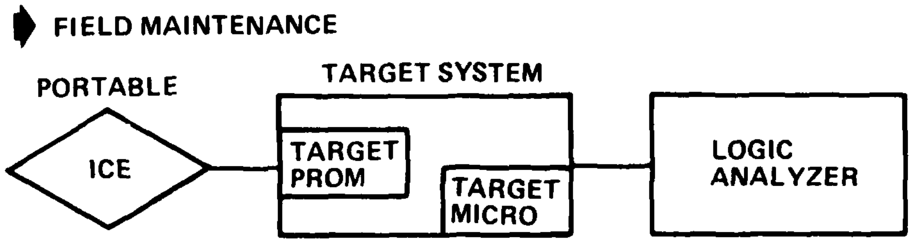
F. Finally, the ICE may be removed, the microprocessor put in its place, and the system operated alone. Here there may still be firmware self-instrumentation and other controls and displays built into the target system.

STAND ALONE OPERATION OF TARGET SYSTEM



- O&M Phase

  G. The ICE can be taken to the field to assist in maintenance of the microprocessor. The MDS with the PROM Programmer is used in stand-by mode for possible program patches.



4.2.4 Languages

The trend in AFSC policy is to require that for non-hardware intensive applications, an Air Force approved High Order Language (HOL) be selected or a waiver thereof be obtained. This is certainly a step forward, but it has some drawbacks. First, the process of determination of hardware/software/firmware intensive application is best determined by an extensive trade study based on change intensity by qualified personnel. The fear is that this may not happen for a number of reasons, i.e., the lack of qualified experts to determine this change rate (there is considerable difference of opinion among the experts as to change frequency to be expected for a particular application). Also, front end costs and schedules are among the primary motivating factors for seeking waivers. Another concern is the differences in Air Force approved languages and those commonly used in commercial applications. Section 4.2.4.1 is from an ASD guidebook descriptions/tradeoffs section for microprocessor HOL's.

For those applications which AFLC intends to support organically, a strong emphasis should be placed on acquiring devices with HOL support during the acquisition process. This can be accomplished via the Computer Resources Integrated Support Plan (CRISP) and through attendance and active participation in design reviews by AFLC agencies. Other emphasis has been in the direction of an Ada HOL or subset thereof for

microprocessor application. With the advent of forced compliance with Ada as a standard, this step will probably become a necessity. A subset will probably come about by marketplace adoption, rather than Government direction.

4.2.4.1 Key Tradeoffs Between Popular Microprocessor HOL's

The following discusses popular microprocessor higher order languages and key tradeoffs between each:

- FORTRAN. Basically a scientifically oriented floating-point language, it requires a large memory overhead in system routines to perform mathematical functions and I/O. As such, it is very inefficient on machines with small word width, small memories, and fixed-point arithmetic units. For processors that can support it, it is one of the easiest languages to optimize for speed. Supports modularity and can be made to support structured programming (e.g., IFTRAN, etc.). FORTRAN is included in the AFR 300-10 list of approved HOL's.

- JOVIAL J73. A block-structured language similar to PL/1 and PASCAL. Compilers are currently being developed for several microprocessors. (Also an AF approved language.)

- BASIC. This is (usually) an interpretive language, meaning that each statement is compiled as it is keyed in, compilation usually consisting of compression of the statement. Numbers are held as strings of binary-coded decimal (BCD) characters. This is one of the most flexible languages available, but one of the slowest to execute. This language does not support structured programming, modularity, or fixed-point arithmetic.

- PL/M.† This PL/1-like language, designed to support microprocessors, has data types natural to them. Comparatively little support is available with this language because of its immaturity. Supports block structure modularity, structured programming, and fixed-point arithmetic.

- PASCAL. Another block-structured language with wide university support. Includes the capability to define new data types. Supports modularity, structured programming, etc.

† Use of these languages for deliverable code requires the appropriate waiver.

- Ada. The proposed DOD standard. This language was designed with embedded applications in mind; however, the full language may be too much for some microcomputers to handle. A reasonable subset will have to be defined in the light of unique microprocessor characteristics and constraints.

4.2.5 Logistics Considerations

There are a variety of wrinkles introduced into the overall logistics management environment by the evolution of microprocessors and firmware. While many of these concepts are not new to AFLC, the new twist is that both hardware and software considerations must be accomplished, and expanded in some cases. The following is a diverse sampling of some of the embedded computer resource considerations. This list is by no means exhaustive, but rather tries to place emphasis on the wide range of considerations which AFLC must entertain. Further management considerations are shown in Table 4-1.

- Engineering specialties. The trend will be away from staffing with the traditional hardware/software split in specialization toward the electrical engineering discipline with digital skills. This is not to say that specialization will not still exist, only that there will be a shift in that direction. Since the trend in ALFC has always been toward the EE discipline, the impact on AFLC will probably be less than on industry.

- Parts distribution. The implementation of computer software in firmware dictates that not only does the program require distribution, but the ROM or PROM must also be available for field implementation. Of course this form of implementation requires additional intermediate and flight line equipment such as PROM burners and verifiers. Preprogrammed chips must be physically dispatched rather than via communication links.

- Parts reliability and shelf life. Although firmware is typically considered very reliable, little is known about the impact that greater gate densities will have on MTBF and shelf life. There is considerable controversy concerning shelf life and environmental conditions for non-military standard microprocessors. The most advisable route is to insist on QPL microprocessors in all applications, where possible, and provide a cool, dry, environment for storage.

Table 4-1. Management Considerations for Common Firmware Devices

Type	Management Considerations
ROM: Read-Only Memory (factory programmed)	• Not programmable by user • Not reprogrammable • Typically less costly • Typically fastest type
PROM: Programmable Read-Only Memory	• Programmable by user • Not reprogrammable • Require PROM programmer • Typically more expensive than ROM
EPROM: Erasable Read-Only Memory	• Programmable/reprogrammable by user • Requires ultra-violet eraser and PROM programmer for alterations • Typically more expensive than ROM/PROM
EAROM: Electrically Alterable Read-Only Memory	• Programmable/reprogrammable by user • Typically expensive • Requires special circuitry within target system • Typically more transparent to user
EEROM: Electrically Erasable Read-Only Memory	• Same as above.

- Market share. Because the Government is a relatively low volume consumer of microcircuit devices, they do not "drive" the development of commercial items. This leads to several problems for management. Because the market is predominantly commercial, vendors do not push as hard for military qualification of their products. Support systems are more directed to commercial applications. While these systems are relatively inexpensive, they are normally not tailored to scientific/military applications and require tool development prior to their use.

- Sparing. The fact that firmware devices require not only replacement due to failure, but also due to changing of mission or system logic has caused considerable problems in logistics planning. To adequately plan for replacement parts several unfamiliar considerations must be understood by the logistics manager. These range from the expected change rate and degree to the number of instructions and memory margin per chip. These considerations are normally out of the purview of anyone except the design and systems engineers and are not available to the logistics planner. It is imperative that data on these technical considerations be made a part of the support planning.

- Maintainability. Because of the reprogrammability of microprocessors and firmware there is additional emphasis on making these parts easily accessible for change. In the case of chips that are reprogrammable under program control or via special equipment/circuits, these too should be accessible through their particular medium.

- Parts availability. Because of the volatile chip market, special emphasis must be placed on availability and sources of replacement chips. Here the best insurance is the maintenance of contractual and other commitments of availability with vendors and the use of QPL parts.

4.2.6 Data Requirements

Data requirements such as Part I and Part II Specs for Computer Program Configured Items (CPCI's) are adequately covered in AFR 800-14 and AFLC Supp. 1 thereto. These aspects of documentation will not be covered here. Only those extensions to these requirements which are additionally needed in the case of microprocessors and firmware will be addressed. The AFSC trend towards identifying digital systems as hardware/software/firmware intensive according to change rate is certainly practical to reduce the delivered documentation requirements; however AFLC policies and procedures must be in total consonance with this

concept for life cycle support problems to be avoided. An error in judgement in establishing the incorrect category for a digital system will have serious long term economic and support impacts. The point is that no common agreement exists between AFSC and AFLC on this issue. The ASD/EN position is that no new firmware Data Item Description (DID) is required, only that existing software and hardware DID's may be modified to embody firmware. While this is certainly a valid assertion, it does not appear to be a consensus. There should be a positive agreement with AFSC on data requirements. Paragraph 4.2.6.1 is an ASD-suggested list of system design aspects which documentation should cover, and another list of questions which documentation should answer about microprocessors.

4.2.6.1 System Design Aspects Covered By Documentation

- Hardware design
  1. Circuit diagrams
  2. Clock and timing data
  3. Memory design
     a. Type
     b. Physical characteristics (including access times)
     c. Logical characteristics (including word length, number of words, error detection and correction)
  4. I/O design
     a. Physical characteristics (bus design, timing, current and voltage levels)
     b. Logical characteristics (path widths, program addressability)
  5. Hardware/software interface
- Software design
  6. a. Algorithms
     b. Logic flow
     c. Source listing

d. Object listing

e. PROM programmer input listing

7. Design tools

a. Support software

b. Development systems

c. Test and diagnostic tools

Microprocessors typically have complex memory structures for which complete documentation is essential. Some things to investigate are

- Physical address space. What types of chips implement which addresses, what are their access characteristics? For example, read only or read write.

- Logical address space. What addresses are available, what is the behavior of each memory location, is there any memory-mapped I/O, are there any "holes" in the address space?

- Anomalous behavior. What is access behavior at unused addresses, what side effects, undefined conditions, etc., are there? Can two or more processors access the same memory? What about interlock protection?

- Unprogrammed state of the firmware device. All 1's or all 0's?

- Patches. Can firmware be overwritten or just programmed once? Can it be erased and reprogrammed? Are firmware components soldered in place or in sockets for easy removal?

- Firmware identification procedures. External (ink stamp, tape, tag), internal (electrically readable).

- Step-by-step procedure. Includes all operator commands and actions, to generate firmware, erase, and reprogram.

4.3 RECOMMENDATIONS

- Formulate a joint AFSC/AFLC regulation concerning microprocessor and firmware definitions, concept of operations, configuration management practices, policies, and procedures. This should include policies on HOL's and data requirements and the need for firmware DID's.

- Develop and install a standard, well-equipped, growth-oriented microprocessor laboratory at each of the five ALC's.
- Provide support for the development of an Ada language for microprocessors.
- Provide guidance for the incorporation of microprocessor and firmware implications into the logistics planning process.
- Insist that AFSC provide data on microprocessors and firmware, sparing requirements, storage environments, shelf life, and parts agreements.
- Establish a joint AFSC/AFLC/Industry study group to standardize identification and labeling of programmed and programmable devices.

5. AFR 800 VERSUS AFR 300 SERIES ACQUISITION/SUPPORT

5.1 BACKGROUND

Considerable confusion exists with regard to the acquisition of computers to provide for ECS support. This confusion was apparently introduced by the long standing policy that all ADPE (which is interpreted to include practically all computers) was managed by AC under the 300 series of Air Force regulations. With the release of AFR 800-14 in September of 1975, there was apparent conflict in interpretation between this regulation and AFR 300-2 in that ADP resources in combat weapon systems and special designed equipment were excluded from AFR 300-2 policy. The ADP single manager concept remained in effect under AFR 800-14 and therein additional confusion prevails; i.e., what is the role of the ADP single manager? Since AFR 300-2 recognizes the existence of Air Force computer resources to be managed under AFR 800-14, the major problem is the extent to which AFR 800-14 applies to <u>dedicated</u> ECS computers and the approval authority vested in the ADP single manager. This review and approval authority is perceived by AFLC ECS managers as resulting in AC approval of MM engineering actions; i.e., the AC ADP single manager has the authority to influence MM actions without commensurate responsibility to accomplish the mission assigned MM.

It must be stated, however, that this problem is not unique to the ALC's, AFLC, or even the Air Force. The requirement for separate approval and procurement paths for weapon system and/or support system computers and other system components appears to exist for all services. In addition, because of the varied interpretations placed on the available guidance at the DOD and service levels, this guidance becomes confusing and contradictory. The overriding reason for this confusion is typically blamed on the implications of PL 89-306 (Brooks Bill); however, it appears that most of the problems are caused by implementing regulations and the interpretation thereof, rather than the law itself. It is commonly agreed that PL 89-306 is general in nature, imposing economical and efficient procurement of automated data processing equipment without providing a specific definition for ADPE. Since the problems facing the ALC-ECS manager appear to emanate from the DOD level, it would be foolhardy to try to solve them at a lower level. While

it is also commonly agreed that the revolution of computer technology has substantially changed the very circumstances which prompted the Brooks Bill, it is not within the purview of this paper to suggest its repeal, even if it appears long overdue. Because this paper is not concerned with the problems associated with major weapons system acquisition, but rather with the concerns of the ALC manager charged with engineering support for ECS, the paper will emphasize the development and operation of support facilities; however, the problems are similar for acquisition managers.

5.2 DISCUSSION

The interpretation leading to the method of procurement directly affects the time required to have an operating support facility on line. The PAR/DAR process is generally expected to require three years for the entire approval cycle, while normal local procurement takes on the order of months for the completion of the approval cycle. The procurement process and support system (AISF) development time must be added to the approval cycle before a system is ready for support. This timeline could very probably provide a system that is obsolete before it is operational.

Another disadvantage of AFR 300 acquisition is the impact of split procurement (AFR 300 for processor and peripherals/AFR 800 for other AISF elements) which must play together to satisfy an equipment IOC. In this case, the AFR 300 acquisition is practically always the pacing factor when equipment is acquired through the DAR process; then all upgrades or maintenance activities to software and hardware are hobbled by the DAR process, extending the time for any modification. These delays are not conducive to mission responsiveness. This also makes more difficult the process of contracting for engineering services when organic resources are not available. This is brought about by a basic philosophical difference in management approach between AFR 300 and AFR 800 series regulations (e.g., doing the job to the degree that a normally fixed set of resources can accomplish versus getting the job done to a defined level, drawing upon whatever resources can be mustered).

Procurements appear to be driven towards AFR 300 or a nonresolved status because of a lack of understanding of the role of the ADP single manager. This situation is further complicated by the fact that the AFLC Computer Resources Review Group (CRRG) is chaired by a designated representative of the Command ADP Program single manager. This is perceived in the field, and is apparently true, as signalling increased involvement by ACD in embedded computer matters.

While the issue is confused at the lower ALC working level, periodic directives and interpretations in the name of implementation of PL 89-306 tend to foster an unsettled atmosphere and uncertainty at all levels contributing to the status quo. Recent perturbations which had the most impact were the proposed DODD 7950. 1, "Automatic Data Processing Resources Selection and Management" which was vague in its exclusion clause which states in part, "when items of ADP equipment (and software developed therefor) are specially designed (not configured) and/or when physically incorporated as a part of a tactical, weapon, or space system or manufactured for the Government under a development contract — unless such resources become excess to the needs of the DOD component." While this description is open to interpretation, it does not appear to encompass many ECS categories in the support area; e.g., simulation host computers, computers embedded in automatic test equipment, engineering data reduction and analysis facilities, and many others. The impact of this proposed directive has been discussed and courses of action proposed within AFLC and the JLC's; however, concern has been expressed by AFLC staff personnel over the interpretation taken by "watchdog" agencies such as GAO, GSA, IG, etc. Another detrimental effort was the GSA proposed reclassification of ECS computers into FSG 70. While the JLC's and the Deputy Under Secretary of Defense Research and Engineering for acquisition policy has taken vigorous exception to the reclassification effort, the matter is yet to be resolved.

Several positive actions have recently taken place which provide some cause for optimism in this area. Most of the progress to date stems from JLC concerns/efforts and some support from the Office of the Deputy Under Secretary of Defense Research and Engineering. These

positive actions began with the submission of proposed changes to DODD 5000.29 by the JLC's. The primary purpose of these proposed changes would be to clearly define embedded computer resources as including commercial computers used in defense systems or embedded in equipment which is used in defense systems. The change further clarifies the definition of "embedded" to include any computer resource which is integral to the operational system or a supporting subsystem. That is, computers would be classified as embedded based on configuration as well as design. This proposed change was considered by the Executive Board of the Management Steering Committee for Embedded Computer Resources and representatives of the ADP Policy Committee, OASD(C)DDA. Several conclusions were reached at the initial meeting:

- JLC concerns over duplicate approval and acquisition channels for weapons systems computer resources and other weapons systems components were appropriate.
- The technical and management environment has changed radically since computers became an item of special (legislative) management interest.
- End-item exceptions (to ADPE acquisition policy) should be maintained for embedded computers regardless of origin, whether obtained commercially off the shelf, or specially designed.
- A full-time working group should convene to analyze the recommendations of the JLC.

The above conclusions and the establishment of the ad hoc working group on embedded computer resource acquisition policy are encouraging; however, it is now even more important that AFLC keep the momentum going by pressing for the adoption of the JLC proposed revisions to DODD 5000.29. Another positive aspect of the JLC initiatives in this area is that they do not advocate circumventing the intentions of PL 89-306, but rather aim to ensure that the intent of that law is provided through the acquisition review process established by DODD 5000.2 (the Defense Systems Acquisition Review Council, DSARC) for major systems. The proposed revision further provides that DOD components incorporate provisions in their review process to ensure that cost-effective procurement is met. This would closely align the acquisition of system-related computer

resources to the system acquisition process. It also provides that these embedded computer resources may be procured without a delegation of procurement authority from GSA.

The JLC PL 89-306 policy application subgroup of the joint policy coordinating group on computer resource management recently concluded a study on the impact of the law on defense system acquisition. While the findings were directed at the acquisition of major weapons system computer components, they could just as well have been made concerning the acquisition of support systems. The findings of that study were that, within the context of the Brooks Bill and in conformance with GSA rules, redundant approval and acquisition channels could be eliminated. This finding led to the JLC actions in proposing DODD 5000.29 revisions. The approval of those changes will have a most positive effect on ECS support; however, the implementation must provide clear and unambiguous guidance in support of these changes.

5.3 RECOMMENDATIONS

This acquisition issue is currently being worked by the Joint Logistics Commanders; therefore, no alternatives are suggested other than to continue support of the JLC initiatives toward adoption of the proposed changes to DODD 5000.29, which follow.

1. The changes to DOD Directive 5000.29 recommended herein will ensure that embedded computer resources for Defense systems are managed consistently and in accordance with P. L. 89-306 (Brooks Bill) and Title 10 U.S. Code which govern systems acquisitions. In addition, these changes will set policy standards governing computer resource acquisition for all DOD components and greatly simplify procedures for program/project managers. Guidelines, similar to the rationale provided below, should accompany the changed directive in order to clarify interpretation of its provisions.

2. The following changes are proposed:

   a. Change paragraph II. B to read as follows:

      "Its provisions encompass major programs of Defense systems acquisition, as designated by the Secretary of Defense (described in Section D of DOD Directive 50000.1, reference (a)). In addition, it provides

principles to be applied in the acquisition of Defense systems that do not fall within the 'major acquisition category.' Included are all computer resources, including general purpose, commercially available computer resources which are embedded in Defense systems or embedded in equipment which is used in Defense systems. The primary purpose of such equipment would not be ADP but some other function such as automatic test, fire-control, antenna switching or radio transmission. The Decision Authority who has cognizance of the system or equipment shall determine if the said system or equipment is an embedded Defense application and hence falls under the provisions of this directive."

Rationale: This paragraph spells out that computer resources included under the provisions of this directive are those which are embedded in Defense systems or in equipment used in such systems. General purpose, commercially available computer systems are specifically stated to be covered because they have been the major problem in this area. Under the previous version of the Directive, use of commercial components was discouraged by the need to process requests through multiple layers of DOD activities specializing in acquisition of ADPE for business type uses. This intermediate DOD layer also makes it difficult to interface with GSA to get exemptions for Defense type applications. The time delays caused by this processing encourages Defense system managers to choose specially designed computer resources even though standard commercial assets may be cheaper or more reliable. It is recognized that some acquisitions will be ambiguous and cannot be readily categorized as a Defense or non-Defense application. Examples of such applications could include training and other such subsystems which directly support one or more operational systems. This paragraph explicitly states that the cognizant Decision Authority for the system will make the determination for Defense applicability in the case of ambiguous applications.

b. Change paragraph II.C to read as follows:

"C. Excluded from the provisions of this Directive are non-Defense Automatic Data Processing Systems and Automated Information Systems assets as defined and administered under OMB Circular A-71 and DOD Directives 4105.55, 4160.19, 5100.40, 7920.1 and 7920.3 (references (b), (c), (d), (e), (n) and (o)). Examples of excluded systems are general multipurpose applications such as Management Information,

Inventory Control, or Payroll systems. However, when feasible, the terms, tools, and techniques employed in the general purpose area will be adopted or adapted to support management of computer resources in major Defense systems."

Rationale: This paragraph makes clear that computer resources are not included under the terms of this directive when they are used for general multi-purpose applications. The intent is to address the computer resource acquisition issue on the basis of application (embedded as a component of a Defense system or general purpose ADP) rather than on the basis of the design of the hardware (specially designed or off-the-shelf). This paragraph also states that resources which are employed to process ADPE procurement in the general ADP area should be used by acquisition managers when appropriate. The difference is that the approval process will be under the control of the Defense acquisition management community rather than the financial community, which is currently the case. Acquisition managers are merely making use of established resources.

c. Insert new paragraph V. A. 3 as follows:

"To ensure cost-effective procurement, embedded computer resource acquisition shall conform to the intent of P. L. 89-306 (Brooks Bill). In the case of major Defense systems, the system acquisition process as specified in DOD Directive 5000. 2 (reference (g)) provides the mechanism which will ensure proper evaluation of embedded computer resource procurement. Specifically, the Decision Coordinating Paper (DCP) for Milestone II will address computer resource requirements and provide an analysis which shows that the proposed embedded computer resource selection is the most cost-effective and competitive choice in the context of system requirements. The Defense Systems Acquisition Review Council (DSARC) will evaluate the proposed selection and recommend approval or disapproval for the consideration of the Secretary of Defense. In the case of less than major Defense systems, DOD components snall incorporate provisions in their review process to ensure the principles outlined above are met."

Rationale: This paragraph implements management and acquisition of computer resources through the highly effective acquisition review process established by DOD Directive 5000. 2. The DSARC ensures comprehensive consideration of all technical and financial [illegible]. Since computer resource acquisition would

now be closely integrated with the system acquisition process, duplication of effort and requirements for approval from authorities who have no responsibility for the system acquisition would be eliminated.

d. Insert new paragraph between the current V. B and V. C paragraphs as follows:

"<u>Acquisition of ADPE</u>:

(1) Acquisition of Computer Resources: Specially designed (not configured) computer equipment, or commercially available computer equipment which is acquired by a contractor and embedded as a component of a Defense system for delivery to the government may be acquired by DOD components without a delegation of procurement authority from GSA. Approval for acquisition of embedded computer resources shall be delegated to the lowest level practical and in most cases to the System Program Manager. Specifications for embedded computer resources must be written to enhance competition.

(2) If the government provides general purpose computer equipment or specifies a particular vendor, a Delegation of Procurement Authority (DPA) must be obtained from GSA. Each DOD component will ensure that duplicate approval of computer resources is eliminated and that paperwork associated with each DPA is minimized."

Rationale: The intent of this paragraph is to specifically state those cases of computer resource procurement which do, and those which do not, require delegation of procurement authority from GSA. This statement should provide clear guidance to DOD components and eliminate the confusion that typifies authority's reaction to most requests for procurement authorization.

e. Change paragraph VI. B to read as follows:

"DOD components shall implement the specific provisions of this instruction through the policies and procedures for which they have cognizance. DOD components will review their existing regulations, specifications, and standards. They shall modify, cancel, or supplement them as required to ensure consistency with the policy in this directive. Implementing directives will specify the method of acquisition (DODD 5000.29) of all computer resource components or systems."

Rationale: The intent of this paragraph is to clearly state that DOD components must implement the policies and procedures of DOD Directive 5000.29 for all system acquisitions, not merely for major Defense systems. This should serve to decrease some of the confusion within DOD components and also specify where the authority and responsibilities lie.

f. Change definition D, "Computer Programs," to read as follows:

"Computer Program. A series of instructions or statements in a form acceptable to computer equipment, designed to cause the execution of an operation or series of operations. Computer programs include such items as operating systems, assemblers, compilers, interpreters, data management systems, utility programs, and maintenance/diagnostic programs. They also include application programs such as electronic warfare, communications, electronics, operational flight, strategic, tactical, automatic test, crew simulator, and engineering analysis programs. Computer programs may be either machine dependent or machine independent, and may be designed to satisfy the requirements of a specialized process of a particular system or support system."

g. Change definition G, "Embedded," to read as follows:

"Embedded. Adjective modifier; integral to, from the design, functional, procurement, operations or support point of view espoused in DOD Directive 5000.1 (reference (a))."

Rationale: The intent is to specify the entire Defense system environment as the encapsulation of the embedded computer resources. Thus, any computer resource which is integral to the operational system or a supporting subsystem would be classified as embedded in the the Defense system. This would include such applications as training, maintenance, analysis, diagnostic, and logistic subsystems as well as special and automatic test equipment which directly support the operational system. The Defense community must control these areas to produce effective systems, on schedule, and at reasonable cost.

h. Add definition I, "Embedded Computer System," as follows:

"Embedded Computer System. A configuration of computer resources which is integral to a Defense system and has the primary purpose of controlling, sensing,

interpreting, processing, or otherwise assisting the operation of a larger system."

i. Add the following references:

"(n) DOD Directive 7920.1, "Life Cycle Management of Automated Information Systems," October 17, 1978"

"(o) DOD Directive 7900.3, "Life Cycle Management of Automated Data Processing Systems," DRAFT"

6. CONFIGURATION MANAGEMENT

6.1 BACKGROUND

To fully capitalize upon the weapon system flexibility facilitated through embedded computer system software, an affective, efficient configuration identification, control, and status accounting system is mandatory. While the import of Configuration Management (CM) for hardware has long been recognized and successfully effected, software — in its less visible, more pervasive nature — has not been as appreciated or manageable. In the absence of effective CM, particularly in a multi-baselined environment, ECS volatility limits, if not totally denies, the flexibility fostered in software. Recovery from such a state is a verbotenly expensive engineering reconstruction of the past change process, usually traversing backward to a point in time wherein a clear linkage can be effected between functional, allocated, and product baselines.

6.2 DISCUSSION

As stated in AFLCR 800-21, the purpose of configuration management is to apply necessary direction and surveillance to identify and document the function/physical characteristics of ECS equipment, CPCI's, and documentation as well as to control changes to these characteristics and report change status. Historically, the implementation of hardware CM has been successful. The majority of the problems associated with CM of ECS is with the software (or firmware) and its documentation. The reason for this probably lies with the less tangible, less visible nature of software.

The basic elements for CM are categorized as follows:

- Policies and procedures
- Identification methods
- Established baselines
- Change control methods
- Implementation
- Resources

6.2.1 Policies and Procedures

The configuration management guidance provided in AFR 800-14 and AFLCR 800-21 is considered adequate. The process of detailing of this guidance into lower indentured procedures and tool requirements at the ALC level (e.g., envelopment into MM MMI MME, MMEC operating instructions), however, has not been consistent across the ALC's. As a result, the Operational/Support Configuration Management Procedures (O/S CMP's) currently in circulation vary in content and appear oriented more toward CM planning than toward CM procedures. In many cases, further detailing will consequently be necessary prior to entering the software change process. Detailed CM procedures/requirements, if standardized across ECS's and ALC's, would result in much more commonality between O/S CMP's generated for the various ECS's, as well as data management systems, requirements tracing tools, and library systems.

While there will be some degree of difference across a given type ECS software (ATE, ATD, OFP, EW, G-E), the establishment of a generic set of procedures and CM tools for each type appears reasonable. It should be pointed out that the attempts that have been made in this regard (e.g., at WR-ALC) are encouraged.

6.2.2 Identification Methods

By DOD definition, "configuration identification" is a document or set of documents that defines the configuration of an item. In this sense, it represents one or more material objects (documents). As a part of configuration management, however, it is not grouped with material objects but with operating processes: configuration control and status accounting. It is natural, therefore, when discussing the functions of CM to expand the scope of the term "configuration identification" to that of a third process that performs all tasks associated with identification of an item's configuration, including identification of the CPCI's in a system and assignment of unique item identifiers to software and documents.

The Computer Program Identification Numbering (CPIN) system delineated in AFLCR 800-21 adequately provides for this unique identifier

for controlling the physical medium. As allowed in AFLCR 800-21, however, auxiliary methods appear to ensure closer control of documentation; a single CPIN will be assigned to the total CM documentation package of a given ECS program, regardless of the number and types of documents required in identifying the baseline. The cross-use of the contractor documentation tree and numbering system or the appendage of a distinguishing dash number to the CPIN itself, should assist in this regard.

6.2.3 Established Baselines

A well-defined baseline is one of the cornerstones of good CM. Without a defined, identified, and documented baseline delivered by the developing organization, the configuration management process is faced with initial difficulties that are hard to overcome in the best of circumstances and are further compounded by subsequent changes to the original software.

A baseline for software is essentially described by the source code and its documentation. Documentation should describe all atributes of the software such as requirements, design, usage, functional and physical description, inputs, outputs, technical description of the code, and test information.

Inadequate baseline descriptions are existent in OFP, EW, ATE, ATD, and C-E categories. Primarily, this is a lack of documentation or that the documentation is inaccurate and therefore does not reflect the true state of the software. In such a case, software support cannot be performed without reverse engineering. This severely impacts the quality of each product. There are many examples of poor quality software at PMRT. An example was presented in Volume IV of this study which indicated 25 to 40 percent of the programs will not function when initially received at the Technical Repair Center. Similar quality problems exist in all five ECS categories with ATE and EW ranking as the worst.

Based on subjective analysis, it is in the inadequate baseline area that many of the problems in CM originate and continue to exist throughout system life cycle. To adequately define a baseline, the documentation must be appropriate and complete. One of the primary reasons for inadequate documentation is lack of resources. Every effort is resource-limited and every development manager and end-user wants the most for

the available monies. Another problem is that software is less tangible and visible to program managers. Most emphasis is in meeting development testing and production deadlines for hardware. Any problem associated with this activity impacts software development. The net result is that software is the last in the development cycle and suffers most from slippages, changes, or modifications to the program schedule. All effort is in trying to complete software development and integration into the system, and software documentation rarely is adequately prepared and maintained under these conditions.

The pre-deployment performance of verification and validation (particularly by an independent agency or contractor), preferably culminating in a demonstration of supportability by AFLC at PMRT, and the fulfillment of the AFR 80-14 requirements (by AFTEC) regarding software suitability and supportability add significant incentive for having high quality software, a well-defined baseline, and adequate documentation at transfer.

Typically, more than one version of a software product exists even at PMRT due to continued engineering development or optimization efforts. This is normally due to operational considerations and will not be addressed here.

6.2.4 Change Control Methods

O/S CMP's and Operating Instructions (OI's) for change control have been developed by the various ALC's and divisions within each ALC. These procedures vary in quality and rigorousness of control; however, they are a step toward CM of software. For example, the FB-111-O/S CMP avoids use of the TO-00-35D-54 deficiency reporting system and yields no mention of assigning MIP's IAW AFLCR 66-15, while the SRAM and B-52 Offensive System O/S CMP's require rigid adherence to these doctrines. Another problem with existing procedures is that they are not specific in establishing step-by-step rules for what, when, and how to perform a change. Many of these documents are only a repeat of top level guidance given in the primary references for CM; AFR 800-14, MIL-STD 483-490, AFR 63-4, AFLCR 800-21. CM plans often omit procedures for support software. The WR-ALC/MMEC OI 800-14 represents a significant attempt to develop procedures for support software.

Another deficiency noted is the absence of direct correlation of CM plan to the software change process. The requirements for documentation, reviews, audits, and status accounting during the systems engineer ing, change development, change testing, and validating phases are covered but not always explicit.

Other control problems exist due to organizational and employment peculiarities. In some cases, the control authority is split between two organizations without clear delineation of authority. In C-E, many of the Command, Control, and Communications (C^3) systems are a support responsibility of AFLC, yet the systems are one or few of a kind which reside at a user location. Although the configuration management responsibility rests with AFLC, it is actually the user who has the opportunity to amend or change the C^3 system. Furthermore, the user is the agency which first recognizes the need for a system change. If the user is particularly conscientious, any change is coordinated with AFLC prior to its incorporation; however, most changes are unilaterally done and then relayed to AFLC. Operational capability pressures substantiate the user actions, but configuration management actions are implemented by an agency other than that agency with the responsibility.

ATD has a similar situation in that the basic weapon system may undergo a change which requires a change to the trainer. First, there is a requirement that the trainer be concurrently updated with the weapon system or else the trainer loses its validity. Secondly, most of the trainers are located at user sites and are operated and maintained by the users although the overall support responsibility is with Ogden ALC. AFLC has attempted to control the trainer configurations by applying the DEPS concept, yet the dual path of change accomplishment exists. The user pressures are to keep the trainer operative, but assurance of long range support is an AFLC responsibility. This dilemma is extensively addressed in Volume III of this report.

In summary, the change control procedures exist and are adequate. Much improvement could be accomplished in uniformity and specificity, and possibly the process could be made smoother for C-E and ATD.

6.2.5 Implementation

Implementation is the major element for improvement in the configuration management process. Basically, CM suffers in this area more so than from the lack of procedural and regulatory guidance. AFR 800-14 initiates rather explicit guidance and describes a method to manage the configuration of software. Several amplifying documents and regulations, including AFLCR 800-21 (change to AFLCR 800-21 is in coordination), have been published which expand this initial guidance. Given the policies and procedures are adequate, the basic shortcoming of configuration management would have to rest in the implementation. This would indicate one of two things: (1) there is a lack of management emphasis or (2) it is impossible to do the job with current resources. Differences in the degree of implementation vary for each ALC and even between systems at a given ALC. This is partially due to the maturity of each system and the unique circumstances surrounding its development. Implementation is most closely tied to resources and management emphasis.

6.2.6 Resources

The remaining key to good CM is resources. This includes the CM system itself whether manual or automatic, personnel, equipment, and facilities. If an adequate baseline exists and the procedures and regulations are adequate, the only open question is the necessary resources to implement CM. Tasks that determine the resources involved include:

- A specific approval authority must be established
- Master copies of software and documentation must be preserved and controlled
- Development copies of the software must be available for engineering and test uses
- An initial data base for the CM system must be created
- A library of documentation and software must be created with its own accessing and control instructions
- Sufficient equipment, facilities, and personnel must be available to implement all of these activities
- The resources must be considered against some scheme for implementation such as an O/S CMP

Where trade studies so indicate, the use of automated tools should be considered to improve accuracy, speed, and cost effectiveness.

Several problems addressed in preceding paragraphs could conceivably be alleviated through adequate resources. As previously stated, management is under pressure to deliver the most product (capability) for the money. This situation leads to a management perspective of CM in that it takes more time and resources to address CM. This drives software development costs upward. If the management responsibility is to "develop only" and to stay within a budget, then CM enforcement suffers and so does the quality of documentation and software. When considered from a life cycle cost perspective, it is cheaper to catch and correct software deficiencies, ambiguities, and/or oversights early in development as opposed to correcting them after the software design is committed to a particular configuration. On the other hand, developers must have some flexibility to accomplish design and software products or else their productivity rate is too low. There is a tradeoff of how much CM discipline to enforce and the determination of "how much" is more a matter of previous experiences than of following a formula. Experience levels of CM personnel have improved in recent years; however, many of the AFLC systems that require software support are from the era when enforcement of CM discipline was inadequate. As a result, the documentation and software combine into an ill-defined (or in some cases, not described) baseline. Support of such systems poses severe problems both managerially and technically.

6.3 RECOMMENDATIONS

1. Detail the configuration management provided in AFR 800-14 and AFLCR 800-21 into ALC division and branch level procedures, advisedly in the form of Operating Instructions (OI's). Action should be taken by HQ AFLC to ensure that such procedures are consistent across like types of ECS's (i.e., OFP, EW ATD, ATE, C-E). These OI's should be employed as items for AFLC functional inspections.

2. Review the suitability of the CPIN system for controlling baselining documentation, particularly for computer programs employed in a multi-version environment involving more than a single ECS and a single weapon system.

3. Review the O/S CMP outline recommended in AFLCR 800-21 with the thought of reorienting it more toward specific, detailed procedures rather than toward top level planning. The CRISP CM section might warrant change to better accommodate the CM planning aspects. Consideration should also be given to modifying both these outlines to accommodate the various types of software that may be addressed in a weapon system level O/S CMP (i.e., OFP, ATE, etc., including necessary support software).

4. As suggested in Section 3, formulate a generic set of software change activities and associated O&S functions which are applicable across the five ECS types. The CRISP and O/S CMP outlines presented in AFLCR 800-21 should be modified to reflect this partioning. The work breakdown structure at the ALC's should also be adjusted to more closely align with these functions/activities.

5. Implement the recommendations tendered in Section 9 to ensure suitable baseline descriptions are available at ECS PMRT and are kept current (with respect to the physical media) over the life cycle.

6. Enhance accuracy, speed, and cost effectiveness; develop a common set of CM tools (e.g., data management systems, requirements tracing tools, library systems) across ALC's and, where applicable, across ECS types.

7. Through close coordination with AFSC, encourage the pre-deployment use of the procedure format evolving from recommendation 1 and the tools selected in recommendation 5.

8. Reexamine the requirements set forth in AFLCR 800-21 and AFLCR 66-15 regarding the use of MDR's, MIP's, and TCTO's to report, track, and release ECS software changes. A "tailored" process more closely attuned to the software change cycle (for emergency, urgency, routine, and block change concepts) appears in order.

9. Conduct a tradeoff analysis to evaluate centralized change management versus a decentralized process (for C-E and ATD). Roles and missions of involved agencies should be carefully considered. If split software support is determined necessary for a special situation, support should be aggregated at one location with CM performed as a consolidated/coordinated effort.

10. Reevaluate the manpower and staffing plans for each ECS currently entering the inventory to ensure that proper CM resources (tools, personnel, equipment, and facilities) are programmed. Emphasize, where appropriate, the import of effective life cycle CM.

11. Ensure that the training planning recommended in Section 3 adequately addresses CM requirements.

7. FACILITY PLANNING/FUNDING/MAINTENANCE

7.1 BACKGROUND

Extensive resources are expended in the Embedded Computer System (ECS) support facility planning process in attempts to identify and obtain necessary facilities, equipment, and trained manpower. The planning process for the ECS support facility, also called Avionics Integration Support Facility (AISF), involves explicit definition of requirements, estimating the cost of items to be acquired and/or developed and obtaining the necessary approvals for the funding. This process must interface with long approval cycles such as the federal budget cycle and the MCP cycle, and can span over years. Changing personnel in the planning process, vague and changing system and support requirements, cost changes, etc., that go along with a drawn out process further compound the delays within the ALC's. There is a general feeling of a lack of dedication by the implementing commands for setting aside resources for providing long range support requirements. A particular example has been the planning process which has taken place on the E-3A AISF.

7.2 DISCUSSION

The discussion begins with a description of an ideal AISF planning process followed by an analysis of the performance of the planning performed for the E-3A system. Additional discussions are then provided to emphasize the problem areas.

7.2.1 AISF Planning Process

An ideal AISF planning process is delineated in the sequence shown in Figure 7-1 with the desired time phasing with respect to the ECS life cycle. The steps can overlap with some steps being done in parallel; however, a sequential process is easiest to follow with progress more easily measured. The major steps consist of:

- PMD/PMP documentation
- Preliminary CRISP document
- Establish support concept

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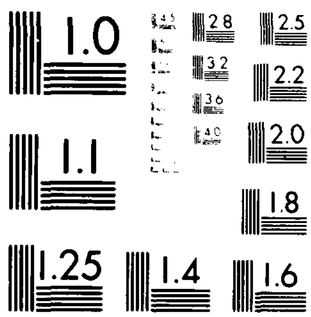

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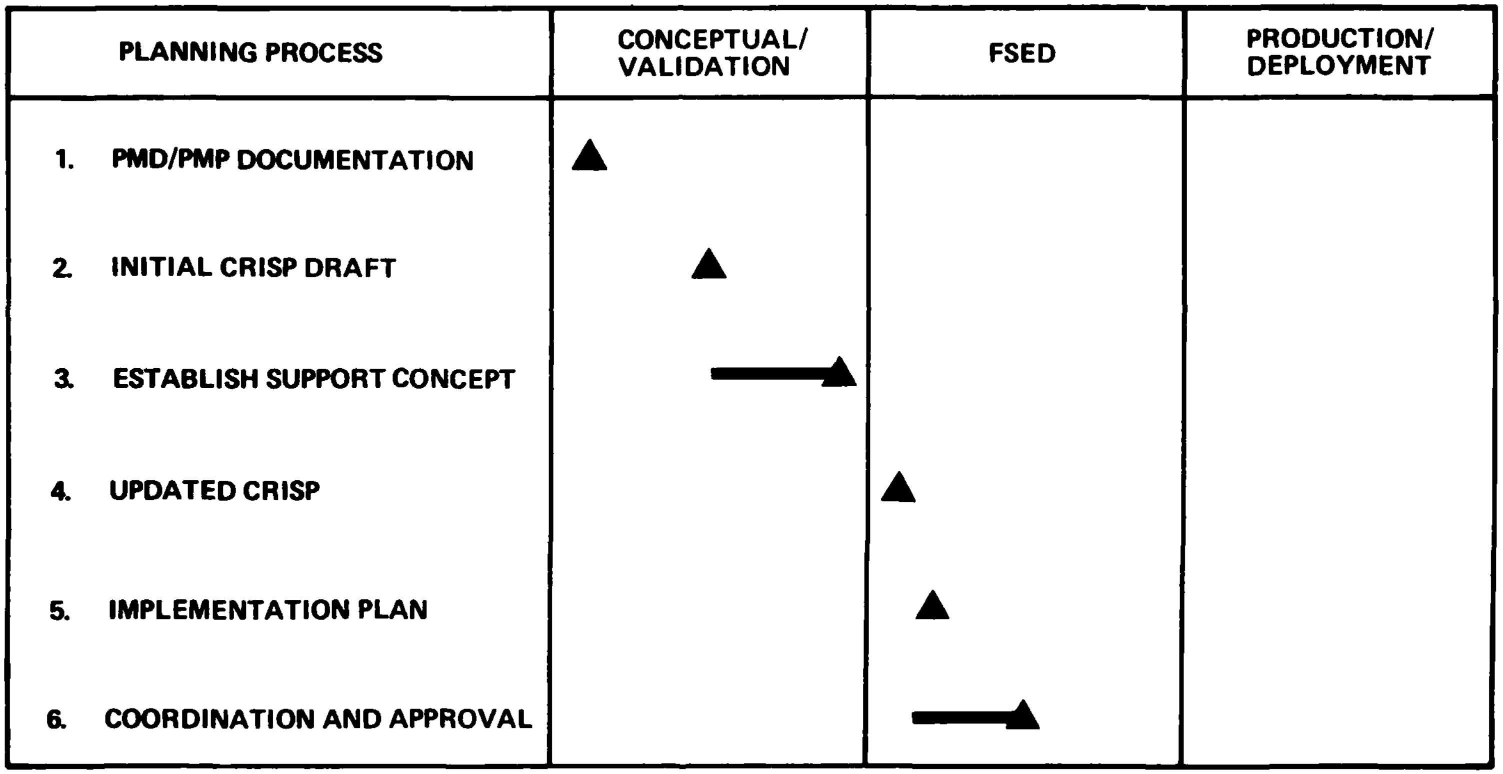

Figure 7-1. Planning Process and Life Cycle Phases

- Update CRISP document
- Implementation plan
- Coordination and approval

7.2.1.1 PMD/PMP Documentation

The PMD/PMP should provide for the establishment of a ground facility to perform software support. It should also clearly state where the responsibility lies. Because the PMD/PMP is directed primarily toward the weapon system, the AISF is often overlooked. When no direction is provided, justification for a need later on is made extremely difficult.

7.2.1.2 Preliminary CRISP Document

The initial draft will attempt to establish how support is to be performed during concept development. Segments which depend upon an established concept, such as organic versus contractor, will be left open to-be-supplied later. This preliminary CRISP document will be utilized to help establish the support concept.

7.2.1.3 Establish Support Concept

Many alternatives exist for performing software support. This step performs the necessary analysis in order to establish a workable concept for support in an austere funding environment. Some of the options include:

- Organic versus contractor support
- Mixed support — some organic, some contractor
- Combined or separate software support and system integration
- Integrated with other multi-system support capability
- Integrated with maintenance capability

Definition is required on the design concepts with ROM cost data established. The Generic Logistic Decision Tree (GLDT) analysis (AFLCR 400-XX) is required to resolve the organic versus contractor question. These analyses are the responsibility of the supporting command.

7.2.1.4 Update CRISP Document

With the support concept established, the CRISP should be completed. The CRISP should now provide details on a support concept such as:

- Management concept
- Configuration management
- Documentation
- Personnel/training
- Support equipment/software
- Facility (brick and mortar)

7.2.1.5 Implementation Plan

With the CRISP defining what is needed, an implementation/development plan should be written describing how to obtain the resources. The acquisition philosophy must be established, such as:

- Items needing development
- Turnkey versus piece part/integration
- Modular approach
- Organic versus contractor integration

In addition (and importantly), the plan should describe:

- Funding (how much, what category, and how obtained)
- Manpower (plans on how to meet the requirements)
- MCP (how best to obtain the needed housing for the equipment)

7.2.1.6 Coordination and Approval

Proposals are made to obtain approvals on funds, manpower, and MCP. This approval process is complicated by the federal budget cycle and the MCP cycle.

With the completion of the planning process, attention can be directed to the next phase of the AISF acquisition/development process

(see Section 7.3 for a discussion of the complete process). The planning process must be completed early with sufficient time remaining in the FSED phase so that AISF development also can be completed in the FSED phase.

7.2.2 E-3A Planning Process

An analysis is made of the E-3A planning process in an attempt to uncover the problem areas causing the long time delays.

A chronology of the planning process is shown in Table 7-1, indicating that the total span was over five (5) years. Remnants of the process still remain. With a projection made of the steps still required to be performed in the AISF development process, as shown in Figure 7-2, the estimated penalty is 2.0 years. With respect to the original PMRT date of October 1980, the penalty would actually be 4.0 years.

It is difficult to pinpoint the problems to one area. Some of the reasons put forth include:

- Delays in the weapon system development
- AISF relegated lower priority over additional aircraft buys and enhancements
- E-3A SPO's continuing insistence on using the development contractors facilities
- Ineffective CRWG and CRISP
- Weapon system complexity
- Aborted contractor studies
- Sole source predicament with large aircraft manufacturer
- Federal budget cycle

Even with the funding approved as a result of the April 1979 in-depth review, many concerns still remain, such as:

- Funds adequacy – what will be the resulting configuration with approval given to the low-end of estimated cost and in the presence of rising costs.
- MCP approval – MCP141-763 approval is still pending.

Table 7-1. Chronology of the E-3A AISF Planning Process

Date	Activity
August 1974	MOA between TAC/AFLC defined division of software support assignment.
December 1974	AFLC's requirement was patterned around Boeing's AIL.
February 1975	Original CRISP issued (Life Cycle Computer Program Management Plan).
June 1975	Cost/Tradeoff study on AIL.
September 1976	SPO initiated a request to Boeing to submit contract change data for support facility.
April 1977	Boeing's CCP issued to perform study (proposal never accepted).
January 1977	OC-ALC reviewed an independent contractor (TRW) study on E-3A support concept.
September 1977	OC-ALC integrated previous analyses in a document entitled "E-3A Software Support Assessment."
September 1977	AISF cost was submitted by AFLC/SPO for entry into FY79 POM at $35M.
January 1978	E-3A overall program restructured replacing $35M in FY79 POM by $9.5M (for transfer of Boeing's AIL).
February 1978	E-3A CRWG subgroup formed to restudy AISF. CRISP reissued.
May 1978	Subgroup presentation to USAF General Officer Steering Group with an estimate of $35.3M to $38.8M.
June 1978	OC-ALC completed a study proposing "Organic Implementation," with an estimate of $35.3M to $48.1M.
Feburary 1979	AFLC/AFSC MOA regarding AISF acquisition concept.
March 1979	MCP for TAFB Bldg. 3220 extension.
April 1979	E-3A in-depth review results in procurement and funding approval for $30.5M.
May 1979	E-3A AISF implementation plan.

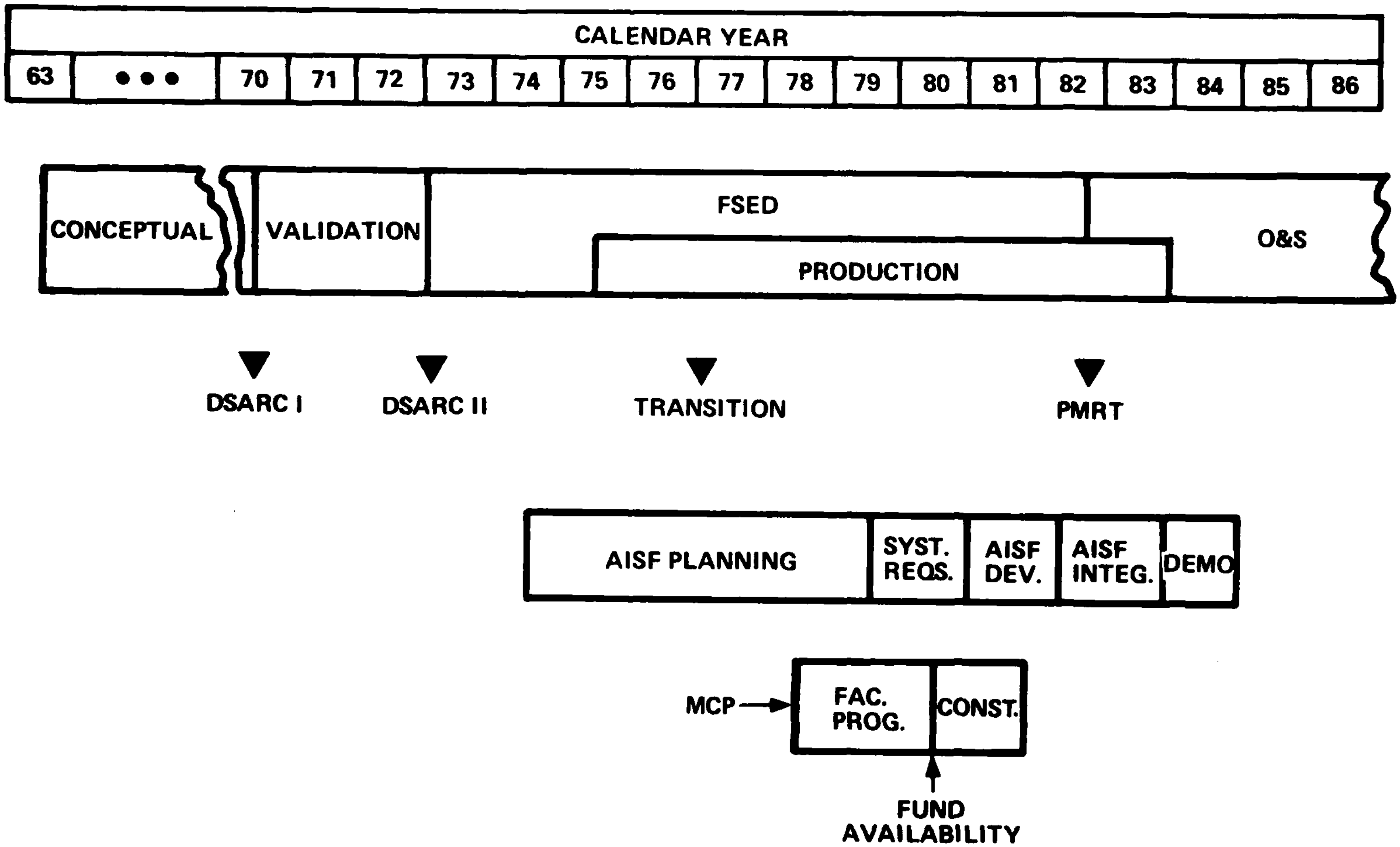

Figure 7-2. E-3A Milestones and AISF Development Projection

- Long lead time equipment – the rapidity with which equipment can be acquired or developed is uncertain. Priority of needed avionic equipment for the AISF over those needed for weapon system production is uncertain.

Some constraints, such as the federal budget cycle and the MCP cycle, are "cast in concrete" and will be very difficult to change. Two items which are disturbing and which should be workable are:

- Low priority given to the AISF
- Contractor's Avionics Integration Laboratory (AIL) versus AISF

Experience should show (A-7, F-111) that software cannot be expected to be troublefree. Even if relatively problem free, users will want to make changes in the software. A ground laboratory facility utilizing actual avionic equipment provides the most realistic environment (short of flight testing) for performing software verification and system integration. This is especially true for highly complex systems where interpretive computer simulations on a large-scale general purpose processor would be very difficult and time consuming. It should be decided early-on whether an AISF is needed. If a facility is needed for software development, an AISF is needed for O&S. If a decision is made that it is required, every effort should be given to the acquisition process. The AISF acquisition should have as high a priority as the software development facility.

The early planning on the E-3A support capability called for the use of the Avionics Integration Laboratory (AIL) which was developed by the prime contractor for use during FSED. The plan was to transfer the AIL upon completion of its activities at the contractor's facility. There are very good reasons why this early plan was not satisfactory, such as:

- Contractors can present convincing arguments against releasing the equipment. ECS enhancements which follow initial development follow one after another tieing up the facility. The AIL originally planned to be available around 1980 is now planned to be used by the contractor until 1987.
- Because the AIL was not developed with intentions of being used by the AF community, documentation is inadequate and the assembly language coding in the environment simulator is difficult to follow.

- Because of the long duration of the development phase, the AIL components need refurbishment and items such as the minicomputer are archaeic and no longer maintained.

In addition, the AIL alone does not provide the software test stands needed for performing software verification, such as the software development laboratory used by the contractor. However, this latter criticism is on completeness rather than on the original support concept philosophy.

Without an extensive tradeoff study substantiating utility, AFLC should resist the concept of "handing down" or transferring to the O&S community the facility utilized during FSED. If and when delivery is made, the facility will typically be too late, badly in need of upgrading, and poorly documented. A support concept must be adopted separate from the development facility. The separate facility can duplicate and parallel sigments of the development facility. However, it is important that they be physically separate. The "handing down" philosophy can only minimize and detract from the full responsibility of establishing the O&S facility. It is too readily used as an easy solution by the implementing command.

Secondly, a clear understanding must be established on the responsibilities of the implementing and supporting commands, especially with respect to funding. It is important to establish ground rules early, such as establishing whether support should be contractor or organic.

It should be noted that having a support capability prior to PMRT can be of great benefit. Valuable experience can be gained in setting up test procedures, familiarization/training on the AISF hardware, and establishing configuration management procedures. Early establishment of a separate facility also minimizes the "sole source" predicament. Depending on the experience gained by organic personnel, the O&S facility can be utilized to scope proposed contractor changes as well as perform independent verification and validation.

There is also a valid requirement that the software which is transferred to the logistics command be supportable. Many times current programs do not allow any time for a demonstration of this capability, or even sufficient time for training to attain this capability. It cannot be

attained by engineers sitting at their desks reading documents. Early establishment of the facility and interactions with the hardware/software is needed.

7.3 SUPPORT FACILITY ACQUISITION/DEVELOPMENT PROCESS

The support facility capability build-up is described in this paragraph as consisting of the five steps or phases shown in Figure 7-3. The steps are basically the same as those for any typical system development. Description of the steps is given in the following, highlighting the important considerations.

7.3.1 Planning

This step has been described in the previous paragraphs. Additional comments follow.

One of the major tradeoffs to be performed is the question of in-house versus contractor in performing O&S. If the tradeoff analysis concludes in favor of an organic support facility, the location at an ALC is established according to where the management responsibility resides. The Generic Logistic Decision Tree (GLDT) analysis will be utilized for the in-house versus contractor determination.

When the location of the facility is established at an ALC, the brick and mortar requirements such as floor space, power/cooling requirements, etc., have to be defined. This determination is required early because any required Military Construction Proposal (MCP) approvals and the needed facility modifications are time consuming processes. This planning will also very likely be interlaced with the integrated support planning being performed at the locale of the proposed facility. Compatibility with the other plannings will be required.

The facility implementation plan should address facility (brick and mortar), equipment, personnel, training, documentation, contract support, and management approaches with emphasis on how implementation is going to be performed. Schedules and funding estimates are the major outputs of this planning task.

With the implementation plan and supporting viewgraphs, a series of reviews will be performed in an effort to obtain approval for the establishment of the proposed facility. Upon receiving approval, the process proceeds to the next phase.

7.3.2 System Requirements

System requirements analyses are performed in this phase to establish a functional baseline for the AISF. The additional trade studies performed in this phase will determine the top level hardware and software requirements. The facility types at this stage should be clear with the complement of the different approaches and tasks selected (scientific simulation, ICS, CMAC, DE, stimulators). The hardware and software configuration items should here be known. This allocation of the AISF system requirements into the hardware and software items is documented into the system specification.

With a clearer picture of the overall configuration of the AISF, an update will be made of the implementation plan prepared initially in the last phase. The schedules should be carefully redeveloped with proper phasing so the system will be available for demonstration at the required date.

In this phase, procurement should be initiated on the long lead time items. One item which stands out is the minicomputer and peripherals required for the simulation host processor. A selection process must be performed, which entails assessing the total SHP requirements including the throughput. It should include such considerations as growth, reliability, cost, integrated support compatibility, etc. Procurement should begin as soon as possible after the selection process so that the hardware and software will be available for full use at the beginning of the development phase. This minicomputer should be available in time for the development of the SHP real time support software.

Another long lead time item is the engineering data base management software. The requirement for this software should include the maintenance of specific data bases (such as requirements) and the use of assistance in performing elements of configuration management. This software should be available early in the development phase. An associated effort

concerns the formation of the AISF software development standards and procedures. Early definition is essential to maintaining configuration control over the development software.

In this phase, any required facility (brick and mortar) modification and preparation should be performed.

7.3.3 Development

This phase begins with the establishment of the requirements for the individual hardware and software configuration items which must either be acquired or developed. The first specification which would be developed will be the Type B specifications written for both the acquired and developed items. The hardware and software items will include:

- Avionics hardware
- Special test equipment
- Simulation software
- Data reduction and analysis software
- Data management system
- Interface units

The development process will proceed as shown in Figure 7-3 for the developed items. Procurement will be initiated for the purchased items. Some support software such as EDMS and simulation models should be available from established facilities at ALC's and other Air Force organizations. Type C specifications will be documented for the developed items and the acceptance test plans/procedures developed for each individual item.

The purchased special test equipment must undergo acceptance testing upon delivery. These items could include the CMAC, the SHP/avionics processor interface unit and the stimulators. Special test software, if required, will be developed and used for testing these special test equipment.

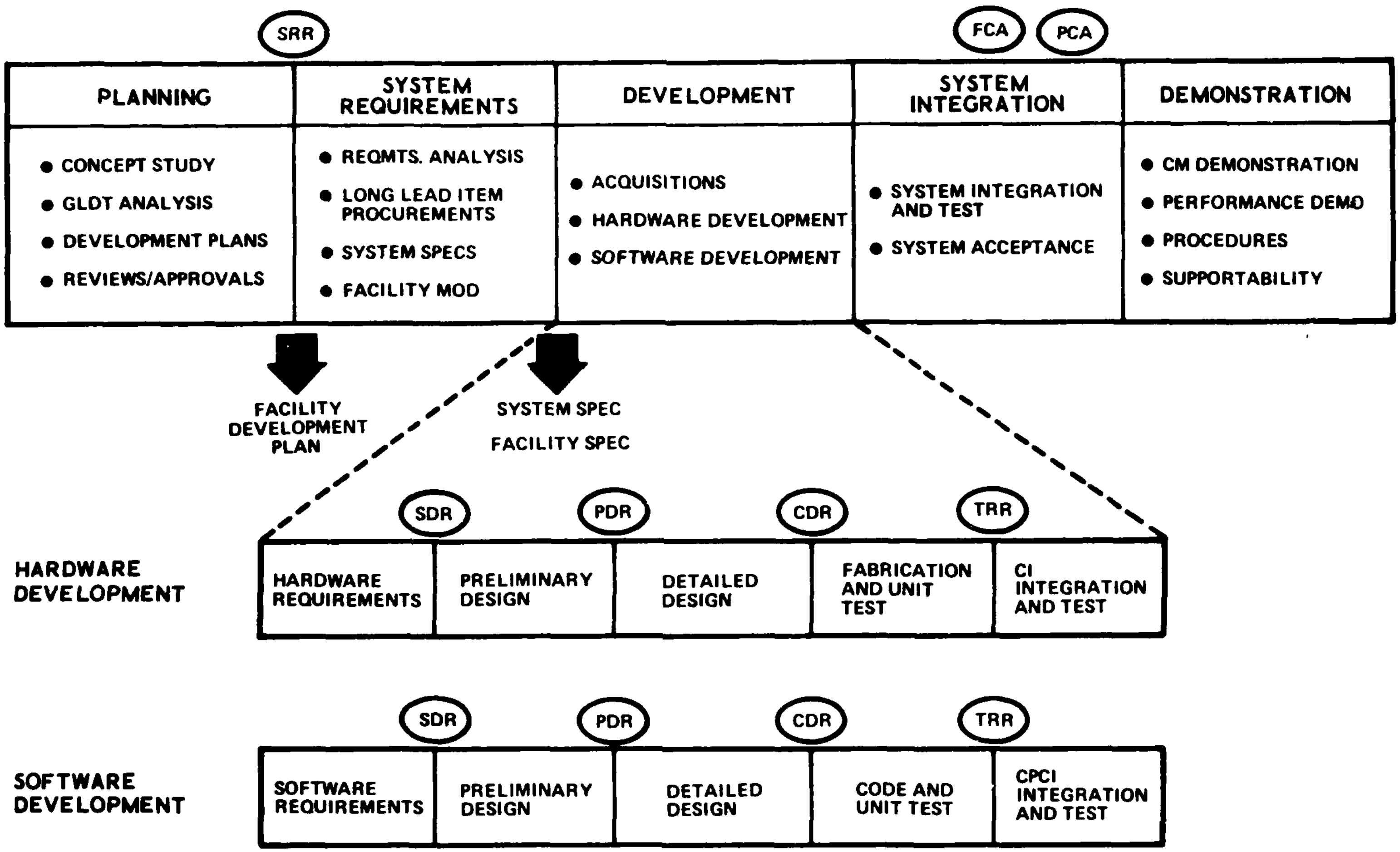

Figure 7-3. Facility Acquisition/Development Sequence

Code and debug of each unit of software is performed before it is integrated with other units of the CPCI. Verification testing of each CPCI is then performed. If special purpose software drivers are needed, they are developed concurrent to the verification procedures.

The final task in this development phase is the development and documentation of the AISF acceptance test plans and procedures.

7.3.4 Integration

The hardware and software configuration items are integrated together in this phase to perform system integration testing.

Initially, a hardware/hardware integration should be performed. During this integration, all hardware is assembled and tested to the extent possible without the AISF real time software. Special test software could be used for this testing. If there are CPCI-to-CPCI interfaces, the software/software integration will next be performed as the necessary equipment become available.

The system integration testing which follows must successfully show that the complete requirements as defined in the Type A and B specifications have been satisfied. Documentation produced and used during this phase consists of the test results document, user's manual, and Type C specification (updated).

Acceptance testing, as per acceptance test plan/procedures, culminates this integration testing phase.

7.3.5 Demonstration

This phase consists of a demonstration of the total system including hardware, software, personnel, and procedures that it is capable of performing O&S on the operational software. It is a demonstration of supportability with its limitations to upper management and interested parties. It should include a demonstration of the CM procedures, V&V, and flight test support capability.

Figure 7-4 shows a top level acquisition/development schedule. The major tasks are listed on the left hand column. The schedule shows where these tasks fall within the five phases. Typical durations are shown for the five phases. In the worst cases, the acquisition/development process can be a 4- to 5-year undertaking. This prospect emphasizes the importance of timely accomplishment of each task and properly time phasing the different tasks to minimize the total development period.

If the software support facility was developed according to the precept of the Air Force policies and procedures, the development sequence of the facility with respect to the ECS life cycle would appear as shown in Figure 7-5. The important time phasing requirement is that the completion of the facility demonstration would occur on or prior to PMRT. As long as this requirement is met, the start of the development process is somewhat immaterial. Overlying the activities are the key planning documentations utilized to define the facility contents.

7.4 FACILITY MAINTENANCE

Planning for the establishment of a software support facility or AISF, by necessity, includes the establishment of maintenance concepts and resource requirements. Some of the considerations which must be made are:

- The source and availability of repair facilities and capabilities.
- The level (concept) of sparing and the availability of funds to accomplish provisioning.
- Concept of repair for commercial products, i.e., original vendor, or third party. Note: while third party repair of commercial computers appears attractive from a theoretical cost standpoint, the time cost in mission support and lost engineering manhours can more than offset the savings of such a maintenance concept. (A third party has the maintenance contract on the Interdata 8/32 at WR-ALC in the F-15 facility. The down-time on that piece of equipment has been as much as a month and more at one time.)

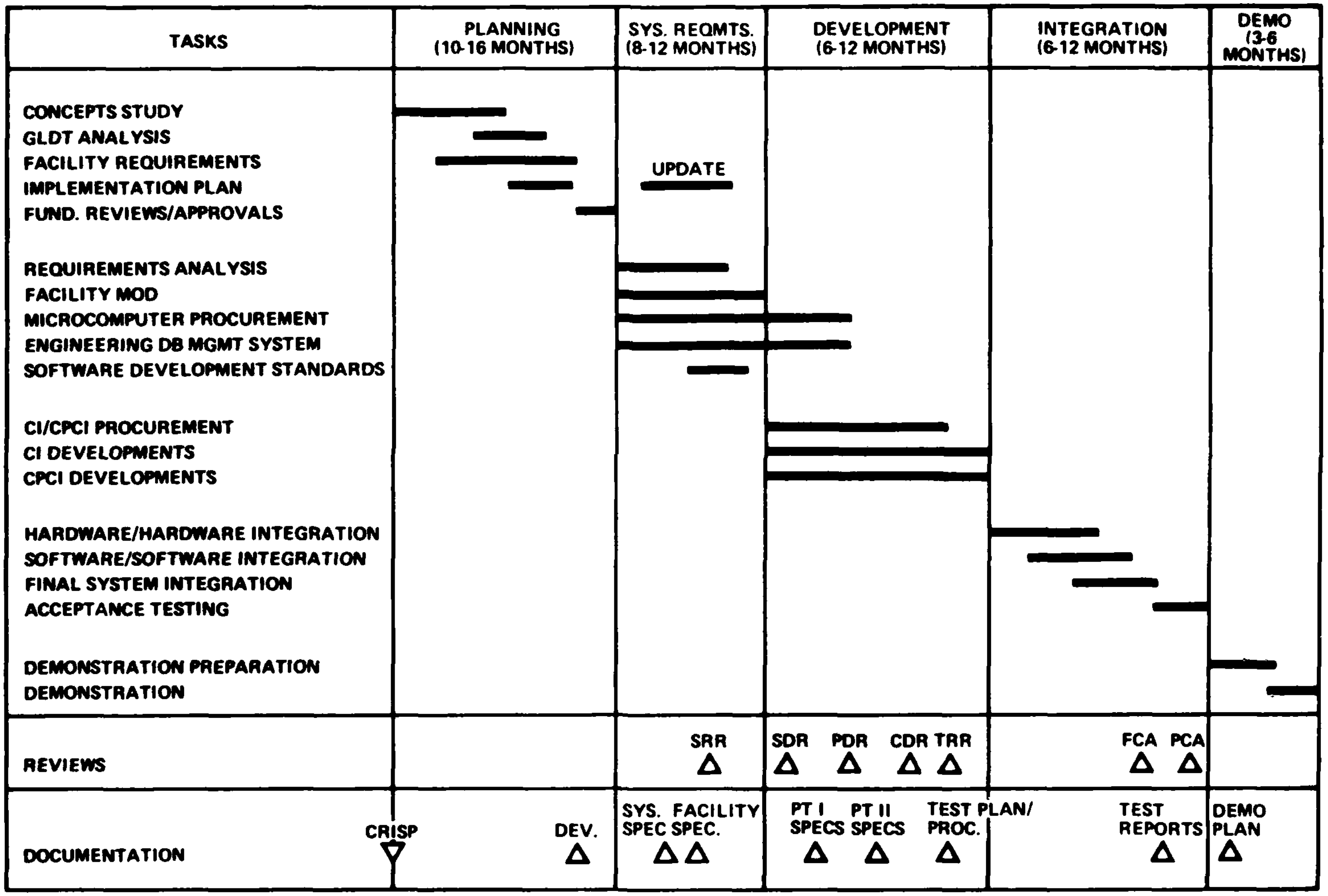

Figure 7-4. AISF Acquisition/Development Schedule

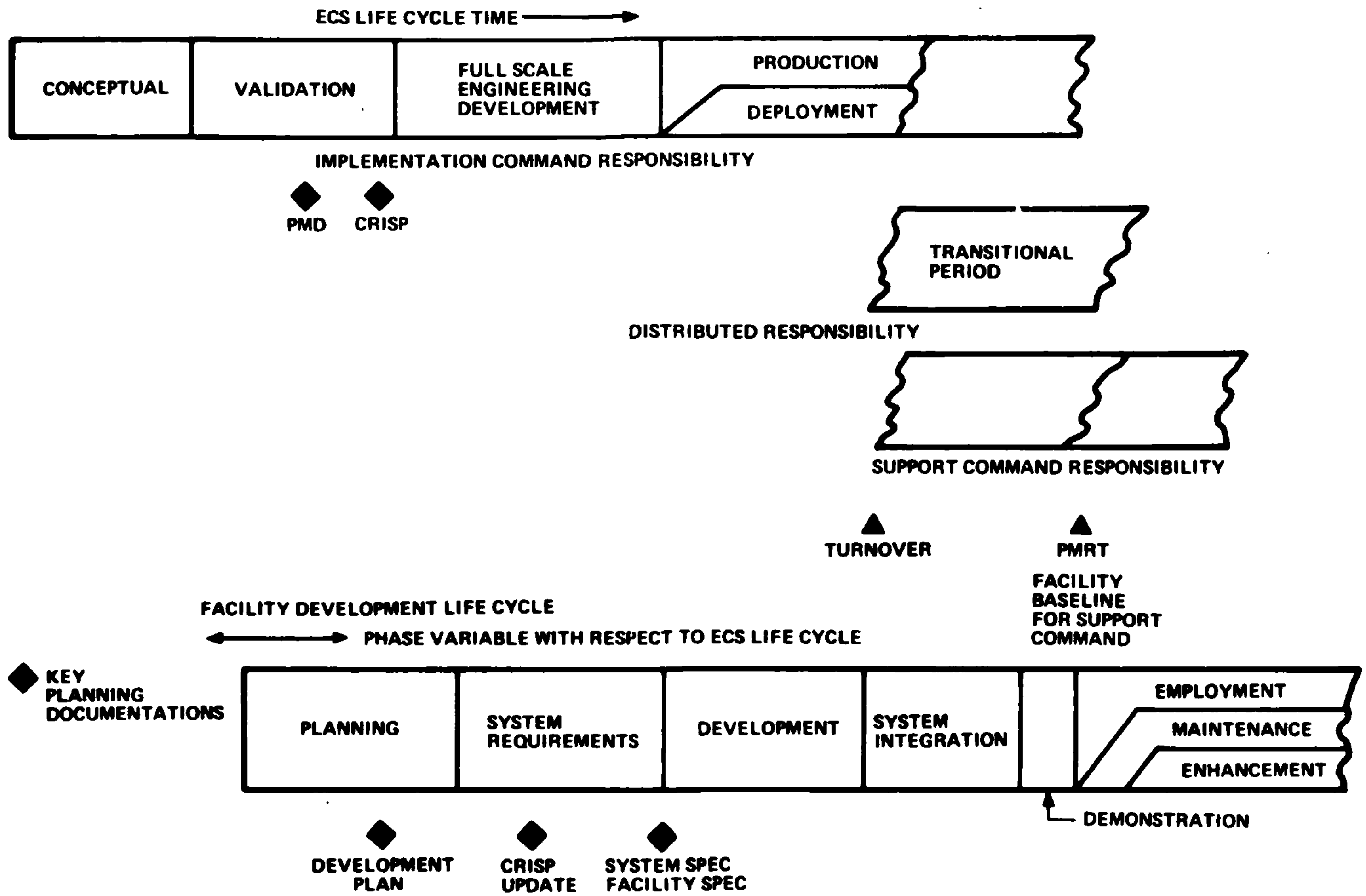

Figure 7-5. Relationship of Facility Development with ECS Life Cycle

AISF maintenance is a multi-task job. The kinds of maintenance range from the commercial electronics to the operational hardware and includes support software.

The various software and hardware to be maintained will be defined. Then a suggested means of maintaining each will be discussed. It is possible that any part of the AISF could be maintained organically or by a contractor. There are, however, some tasks that lend themselves more to one means of support than the other.

7.4.1 Operational Hardware

Operational hardware consists of those aircraft LRU's that are used in the AISF. The suggested method to have these LRU's maintained would be to treat the AISF as if it were another aircraft so that LRU's could be replaced through normal maintenance channels. In addition to this, if the repair facility is at the same ALC as the AISF, an agreement should be made to check the LRU to ensure that it is actually bad before it is placed in the maintenance pipeline. This helps ensure that the problem is in the LRU and not elsewhere in the particular test stand.

7.4.2 Commercial Software

Commercial software consists of software (e.g., operating systems, compilers) that is purchased from a vendor. This software is best maintained by the vendor because applications programmers generally use it as a tool and don't become familiar enough with the software to adequately maintain it. The people responsible for the AISF must determine the impacts of updating commercial software on the applications modules already in use.

7.4.3 Applications Software

The applications software is that software which has been written to drive the test stand (e.g., simulation modules, interface drivers, data reduction, etc.). It should be maintained organically or by a resident contractor (i.e., not a vendor that comes on call). The reason for this is that applications software tends to be specialized and requires people that are intimately familiar with the software to change it.

7.4.4 Commercial Hardware

Commercial hardware is computers and off the shelf equipment. Computers are usually best maintained by the vendor at the location of the AISF. Some of the other commercial hardware does not have repair procedures set up like most computers do. In this case, spares must be bought to keep the AISF running while the bad unit is sent for repairs. Maintenance of all commercial hardware should be considered before it is purchased.

7.4.5 Peculiar Hardware

Peculiar hardware is designed for a specific test stand for purposes such as special interfaces and computer monitor equipment. Spare circuit boards need to be maintained locally for all peculiar hardware. This enables a bad board to be replaced and the test to be completed. The troubleshooting of the bad board can be done without impacting the test. This repair could be performed by organic or resident contractor technicians, when not modifying the test stands or repairing them, could serve as test stand operators.

7.5 CONCLUSIONS

Facility maintenance is important enough to the long term goal of the AISF that it should be considered during the design phase. If it isn't clear that adequate support can be obtained for any given hardware or software, an alternative design should be used. The means of maintenance will be determined by factors other than just the act of maintaining hardware or software. Some of these factors are availability of slots, people, and money.

Table 7-2 provides the recommended means of maintaining the AISF. In the case where organic/contractor is used, it is assumed that either can perform the maintenance equally well and that other factors will determine which one would perform the maintenance.

7.6 RECOMMENDATIONS

1. Develop a coordinated set of AFLC/AFSC guidelines for establishing and maintaining post-deployment software support facilities. These guidelines should address the

Table 7-2. AISF Maintenance Responsibilities

Function	Responsible Group
Operational hardware	Organic/standard repair pipeline
Commercial software	Contractor/commercial vendor
Applications software	Organic/contractor (resident)
Commercial hardware	Contractor/commercial vendor if possible
Peculiar hardware	Organic/contractor (resident)

gamut of planning, development, integration, demonstration, and maintenance activities as well as documentation requirements necessary to ensure that a timely, effective, and efficient capability results. The Software Acquisition Engineering Guidebook for Software Development and Support Facilities recently developed for ASD provides a solid basis for such guidelines.

2. Insist that a support facility concept and requirements study be performed during the conceptual/validation phases of each major program where embedded computer resources are involved to establish the support concepts and tradeoffs which need to be considered. This action, which should be under the advocacy and implementation of AFALD with close interaction with and support from AFLC/LOEC and the ALC's, should be fully coordinated with/approved by all MAJCOMS and interservice agencies involved.

3. As recommended in Section 3.3, take action to establish the CRISP as a USAF-wide MOA for post-deployment ECS resources (viz. support facilities). It is suggested that a request be submitted to the JLC to establish a joint panel to assess the appropriateness of this recommendation.

4. Modify AFR 800-14 and other appropriate guidance to more clearly identify the funding responsibilities associated with post-deployment software support facility acquisition and O&M.

5. Develop a PMD/PMP/ILSP checklist which can be used by HQ USAF, AFLC, AFALD, and field agencies participating in ECS acquisition to ensure that these documents properly address support facilities. USAF/LEOC should be encouraged to non-concur on all PMD's which do not adequately address post-PMRT support facilities.

6. Incorporate facility planning and funding as part of the DSARC process — including these as specific items in the "DOD Embedded Computer Resources and DSARC Process Guidebook."

7. In concert with recommendations tendered in Section 9.3, software support facilities should be established within AFLC as early as possible in the acquisition cycle to capitalize on the benefits of permitting AFLC to carry out pre-deployment activities.

8. FUNDING

8.1 BACKGROUND

The change in AFLC role and the necessity to shift priorities toward more technological and mission-oriented support postures have caused some perturbations on funding levels and distribution. This appears to be due, in part, to the lack of awareness of the ECS role and the basic lack of understanding of the nature of the engineering on the part of all levels of management and fiscal organizations. In addition, the multitude of fund types and the timeliness of establishing funding requirements for software engineering place an undue burden on the ECS manager in planning funding channels. The POM/OOB and EOP/AEP/CEP cycles demand a two-year cycle for funding definitions by category (Section 8.4) while ECS support is mission responsive, necessitating early estimates of the amount and type of change activity to flight software. Two other ECS areas greatly affected are training and travel funds. For both of these categories, appropriations not related directly to ECS have lower priority than other elements (MFP VIII category), leading to the probability that the rest of the requirements may get funded, but not training and travel (i.e., travel and subsistence funds are in perennial shortage at the ALC's). As a result, personnel who will be responsible for support of a new system cannot attend design reviews, program reviews, and other important meetings at which decisions are made that affect the support requirements. Attendance at these meetings is spelled out in AFR 800-14, and failure to accomplish these requirements minimizes front end costs and impacts on LCC.

8.2 DISCUSSION

While this section treats funding as an issue, it is in part only symptomatic of other issues such as:

- Facility planning/acquisition
- Early involvement in the development/acquisition process
- Flexible response to software changes
- Training

Another concern expressed by the ECS manager was split funding which will also be addressed. A federal budget cycle and an MCP cycle are included for reference.

8.2.1 Facility Planning/Acquisition

Traditionally, it is the responsibility of the implementing command to provide for support facilities along with weapon system development and acquisition. This is currently done adequately for all traditional types of support (ATE, engines, test, TRC, etc.), and although the requirement to provide software engineering support facilities is clear in existing directives (DODD 5000.29, AFR 800-14), confusion still exists as to who will fund the facility. This is not a problem with all systems. For instance, little resistance was met in getting the F-15 and F-16 SPO's to meet this obligation; however, for a multitude of reasons, the E-3A AISF planning has been hampered/delayed because of misunderstandings/disagreements in this area (see Section 7).

Another facet of this problem is the necessity to establish facilities that are to be used for multi-system support. When a facility is developed for the unique support of one weapon system, it is clearly stated in AFLCR 800-21 that the individual SPO will fund the effort and the type of funds are clearly defined in AFM 172-1 (3010, 3020). When the facility is multi-purpose, the type of funds is clear (3080); however, ECS managers expressed concern over the justification and approval path, or who was responsible for providing the funding. Because AFLC does not expend funds prior to PMRT, it would appear difficult to establish consolidated support concepts prior to PMRT, contrary to prudent fiscal management. Clearer guidance is needed in the area.

As stated above, funds are now expected to be provided by individual SPO's; however, it is not always promptly forthcoming. The time delay in convincing an SPO that the AISF is a real requirement to be funded out of its already depleted funds can have a significant impact on the timeliness of funding and therefore the operational date of equipment. An example of this delay can be seen in the E-3A program where the SPO was unconvinced for some time that the AISF was a legitimate requirement. Obviously, if AFR 800-14 stated the firm requirement that software

support equipment was to be funded through the SPO (it is certainly implicit) and the weapon systems PMD explicitly called for its funding and support, AFLC planning would be more firm and programmable. This should also be made a part of the DSARC process through the DCP; however, this would require a modification to DODD 5000.29.

Another problem is the lack of a link between weapon system modification and support facilities. Often a modification to operational hardware is approved without providing for the updates to support facilities, trainers, etc., to accommodate the change (if required). For example, funds for the modification of the F-15 AISF due to the programmable signal processor modification were not automatically provided, although the SPO did provide the funds upon request. In some cases, data is not procured to enable the support facilities to be provided later or from alternative funding sources.

8.2.2 Early Involvement in the Development/Acquisition Process

AFR 800-14 and AFLC implementing directives require that support agencies (AFALD, AFLC HQ, item/system managers, MMEC, ACD, MA-T, etc.) provide inputs to the development and acquisition process beginning with the conceptual phase. Travel funds are stated as a responsibility of the particular agency through normal TDY channels (EEIC 40 XX) with the exception of Software Support Center (SSC) requirements which will be program funds. The problem here is the trend toward reducing TDY expenditures while TDY requirements are increasing with the increasing ECS workload. In the light of congressional ceilings on travel expenditures, this obviously is not an easy issue to address. However, since directives state the requirement and the need appears to be valid, some resolution is needed. One method would be to seek approval for ECS related TDY to be funded out of program funds. This may be justified because of the unique nature of the software support mission (more direct labor than overhead oriented).

8.2.3 Flexible Response to Software Changes

The real issue here is the mission related nature of ECS support. That is, the requirement to accomplish changes to a degree necessary to

meet U.S. military and political objectives, rather than to a level dictated by a set level of resources. This impacts the ability of the ECS manager to accurately predict requirements within the budgeting cycle and within the proper budget categories.

The ECS manager is faced with supporting mission requirements with preplanned funding which may or may not be the right type or be sufficient to accomplish required activities. For instance, software change-only funding (EEIC 583-AA-JZ) is different from a software change caused by a hardware change (EEIC 583 UA-ZZ). Also, the hardware modification is funded under a different budget appropriation (3010/3020/3080, BP 1100) than the resulting software change. This brings on the possibility that one may be funded and the other declined or deferred. Another complication is the fact that 3010 funds are three-year funds, while EEIC 583 funds are one-year funds. A tremendous boost to the ECS manager would be the ability to expend 583 funds over three years concurrently with hardware funds financing the same activity. This would also negate the precise manner which the ECS manager has to estimate the year that funds will be required. Accurate estimates of the timing of software activities related to hardware modifications can be difficult, considering delays in modification programs brought about by production slips, congressional funding limitations for hardware, changing requirements, etc.

Contributing to the complications associated with funding appears to be a general misunderstanding of budget categories, qualifications for, and baselining requirements. Contributing to this confusion is the fact that direction is in several documents, letters, etc. Another confusion factor is the difference and timeline between ADPE and ECS funding.

Less than adequate funds are generally included in EEIC 583 due to the prevailing concept of AFLC in the stock-store-issue business. The concept that AFLC is in the digital engineering business with a large mission to perform must be reflected in funding. One of the primary reflections of the lack of recognition of this concept is the difficulty in obtaining funds by the ALC's. It would probably be advantageous to conduct an in-house study to compare costs involved in performing a weapon system modification via software and the postulated costs for performing that

same modification via hardware. This data could then be used to justify additional funds to support ECS, both in the equipment/engineering area and in the TDY area.

Because of the likelihood that less than full funding may be provided in a given fiscal year, a more efficient method of procurement would allow incremental funding of contracts for development of support tools. These type contracts are currently not in widespread use within the AFLC and are restricted by regulation. Recent consideration by the JLC brought about agreement that multi-year procurement to include incremental funding could be used as a method of improving buying performance. While no specific JLC initiatives are known at this time, AFLC should support any effort to encourage DOD and Congress to ease restrictions to incremental funding.

Funding avenues for IV&V of software by AFLC are not well defined. It should be an objective of AFLC (recognized in AFLCR 800-12) to perform or manage IV&V on major software programs developed within AFSC and to have funding for this activity channeled either directly through the program office or through AFTEC to the responsible ALC.

8.2.4 Training

While the requirement for and the responsibility to provide ECS training is well documented, examples of continuous delays are encountered in accomplishing required courses. This is due primarily to the perennial shortage of funds in ATC and the established priorities. The training issue is treated in more detail in Section 3 and in Volume VIII of this report.

8.3 SPLIT FUNDING

In the case of concurrent hardware/software modifications the trend should be away from split funding for engineering change, i.e., currently a block change to a PROM-based system utilizing on-site contractor personnel could be interpreted to require:

- BP 3400 EEIC 583 (AA through JZ) for software changes not related to hardware changes and associated CPIN data packages.

- BP 3400 EEIC 583 (UA through ZZ) for software changes related to hardware changes to include CPIN data.
- BP 3400 EEIC 583 for blank PROM's.
- BP 2400 EEIC 594 for TCTO's to announce the change and support affected T.O.'s.
- BP 3400 EEIC 569 to maintain the AISF equipment.
- BP 3400 EEIC 582 for software changes for general purpose ADPE support equipment (i.e., the Univac 1108 at Warner Robins).
- BP 3400 EEIC 568 for maintenance of the general purpose machine.
- BP 3400 EEIC 592.63 for subscription services for any FSG 70 equipment.
- BP 3400 EEIC 92.35 for software described by vendors in subscription services.
- Either BP 3400 EEIC 54X or BP 4922 to burn and install chips.

These procedures are further complicated if any rented equipment is used, if a DAR is required to acquire additional equipment, if data items require printing, or if a modification to the AISF is required.

The reduction of the number of budget categories in support of ECS support would reduce the uncertainty and difficulty in budgeting funds.

8.3.1 Federal Budget Cycle

The fiscal year budget process is discussed for a given year in very broad terms in order to obtain an insight into how the process can affect a development program. The current process is based on the Congressional Budget Reform Act of 1974 which created a Congressional Budget Office (CBO) which services both Senate and House, created a committee in each chamber of Congress to oversee all budget functions, and changed the FY to begin 1 October rather than 1 July.

Using FY82 budget process as an example, the process event dates are shown in Figure 8-1 which illustrates three principal phases: budget

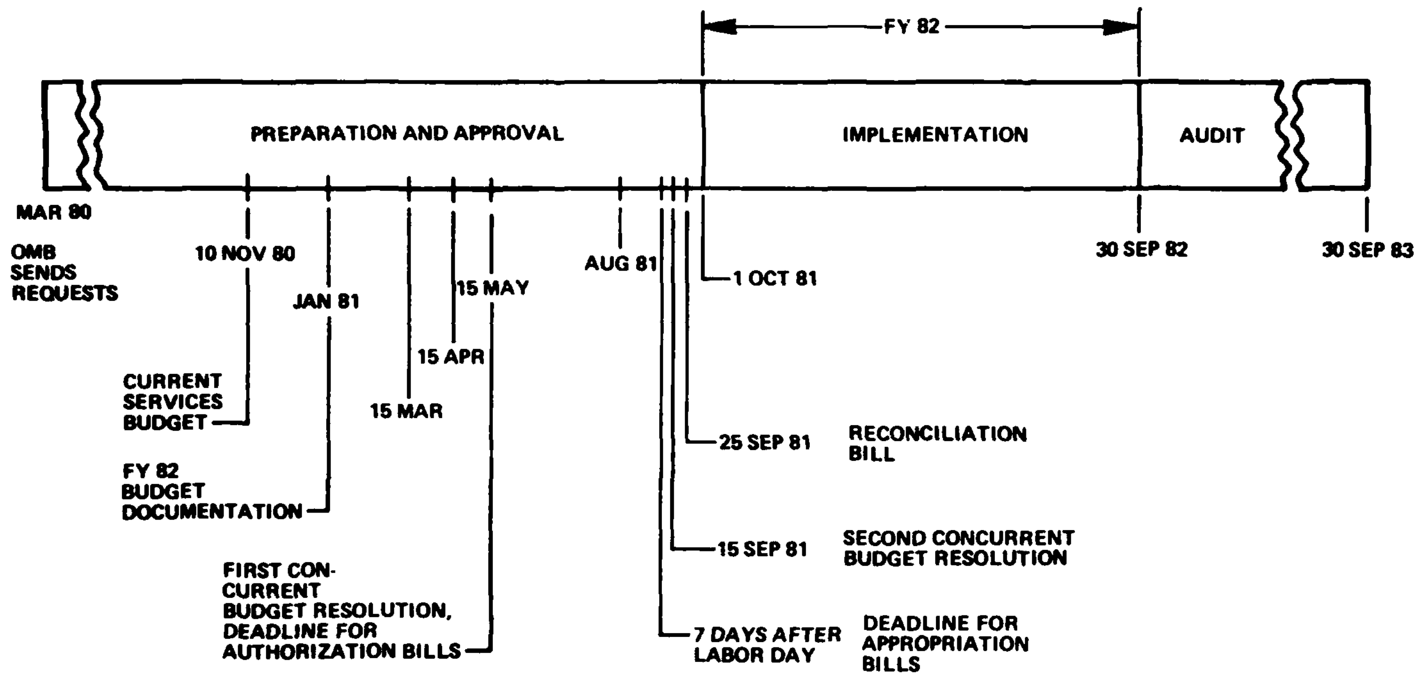

Figure 8-1. Federal Budget Process for FY 82

preparation and approval, budget implementqtion, and budget audit. In the following discussion, focus will be made of the budget preparation and approval phase.

The FY82 process starts in March 1980 when the Office of Management and Budget (OMB), which is responsible to the President, sends a request with some guidelines to each agency and department asking that they begin submitting FY82 budget information through channels to OMB. This requirement is filtered down to the lowest levels of the agencies and departments where budget planning begins with estimates made and approval sought up the chain of command.

On 10 November 1980, the President submits a "Current Services Budget" to Congress. This budget indicates the estimated cost that would incur if the existing services were to continue in FY82 without change.

In January 1981, the President presents his FY82 budget documentation which has been gathered and massaged by each level up the ladder to OMB. This budget projects increases and decreases in expenditures for the various governmental functions and services and estimates incoming revenues. The various committees in the Senate and the House (e.g., defense committee, agriculture committee, education committee, etc.) take the proposed budget and evaluates the requirements of agencies within their area of assignment.

By 15 March 1981, these various committees must provide gross estimates of funds required by agencies within their area of concern to the Budget Committees (one in Senate and one in House).

By 15 April 1981, the two Budget Committees must draw up the first Concurrent Budget Resolution which describes the projected expenditures and revenues. At this time, the sundry congressional committees begin preparing "authorization bills" which will authorize agencies to carry out functions and to expend funds (although funds authorizations are yet to come).

By 15 May 1981, all authorization bills must have been presented on the floor and Congress as a whole must approve the first Concurrent Budget Resolution.

From 15 May 1981 to August 1981, the Appropriations Committee in each chamber (but primarily in the House) prepare the bills to appropriate funds based on authorization bills and compared with the first Concurrent Budget Resolution. During this period, the CBO tracks the budget actions and compares bills for expenditures and revenues with target funds figures. The CBO reports to Congress each week on the amounts appearing in bills versus target amounts.

In August 1978, the Budget Committees look at the present situation, derive more firm figures, and prepare the second Concurrent Budget Resolution.

By seven days after Labor Day, Congress must have finished all appropriations for the coming fiscal year.

By 15 September 1978, Congress must pass the second Concurrent Budget Resolution and ensure that all appropriation and tax bills conform to the resolution. Once this resolution is passed, Congress cannot increase or decrease spending on tax bills unless the changes retain the same total deficit balance shown in the resolution.

The final accounting to ensure that the bills conform to the resolution is in the form of a reconciliation bill passed by 25 September. This reconciles the tax and expenditure bills such that conformance is attained.

On 1 October 1981, the FY82 begins and the implementation phase begins lasting through 30 September 1982.

It can be seen that if funds are to be obtained for any facility function for FY82, the requests must be in the command budget estimates between March and August 1980. This means that plans must be firm 1-1/4 years prior to fund implementation. If approval is not obtained in time, another year can be lost waiting for the next cycle.

8.3.2 Military Construction Program Cycles

The Military Construction Program (MCP) for the facility (brick and mortar) programming, design/construction, initial outfitting equipment funding, etc. is a long, time consuming process which must be considered as part of the AISF planning process. AFLC Regulation 78-4

establishes procedures to be followed in the acquisition management. As the regulation provides details on the schedules, only a summary highlight of the MCP cycle will be described here.

The facility programming, design, and construction along with the outfitting of the building with a mechanized materials handling system (if required) and initial outfitting equipment, require a concerted effort of phasing the various aspects so that unnecessary delays do not occur. Since funds request is tied to the federal budget cycle, a one year slip can easily occur if an important deadline is not met. Figure 8-2 shows the important decision points as well as the phasing of the facility programming steps with the facility design/construction steps so that the construction can proceed as soon as the funds are approved. The steps are briefly described in the following. The FY82 MCP cycle (funds ready for use in FY82) is taken as an example.

A. <u>Facility Programming</u>

A1. The FY82 process starts in October 1979 when the in-year program portion of the Five Year Defense Plan (FYDP) is returned to HQ AFLC/DEP by HQ USAF/PREP. This program is passed on to the centers, with guidance for initial tasking of preliminary planning and project development.

A2. In January 1980, HQ USAF/PREP provides detailed MCP guidance to HA AFLC/DEP, which in turn is provided to the centers.

A3. In January/February 1980, the Center Facility Board convenes to confirm the in-year MCP projects and priorities. The out-year priorities are also developed.

A4. In February 1980, the programming documents (DD Forms 1391/1391C) and the project priority listing are submitted to HQ AFLC/DEP.

A5. In March 1980, HQ AFLC Facility Panel develops the integrated project priorities.

A6. In April 1980, the HQ AFLC Facilities Council convenes to consider the integrated project priorities.

A7. On 1 May 1980, the in-year MCP submittal is due at HQ USAF/PREP.

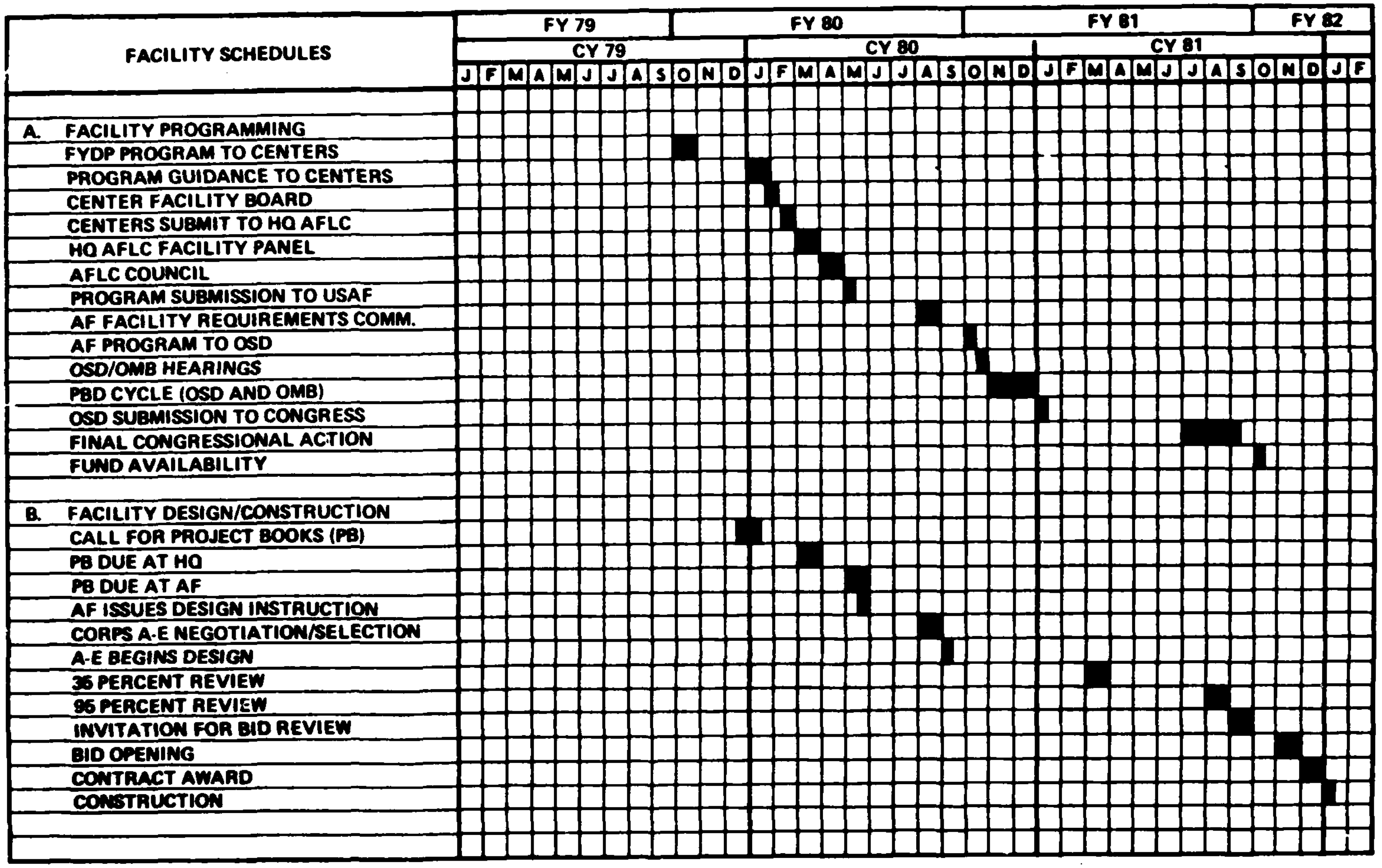

Figure 8-2. MCP Cycles

A8. In June through August time frame, Air Staff meetings are held to review and validate program content. HQ USAF Facilities Requirements Committee (FRC) confirms and finalizes Air Force-wide in-year MCP submittal.

A9. On 1 October 1980, the Air Force in-year MCP is due at the Office of Secretary of Defense (OSD).

A10. In October 1980, OSD/OMB Hearings are held.

A11. In November/December 1980, the OSD/OMB Program Budget Decision (PBD) cycle takes place.

A12. In January 1981, the in-year MCP is submitted to Congress.

A13. In July through September time frame, final Congressional action and Presidential approval takes place.

A14. On 1 October 1981, the FY82 in-year MCP funds are available for apportionment.

B. Facility Design/Construction

B1. In December 1979, development of project books is initiated by the Base Civil Engineering for each project in the MCP. The project books are reviewed and coordinated by the user and support offices.

B2. In March 1980, the project books are forwarded to HQ AFLC/DEE for review and approval.

B3. In May 1980, the project books are forwarded to HQ USAF/PRE for their cursory review.

B4. In late May 1980, HQ USAF/PREE issues the Design Instructions (DI) to the appropriate Air Force Regional Civil Engineer (AFRCE). The DI identifies the design agent; USAF approved project scope, and programmed amount.

B5. In August 1980, the design agent (normally the Corps of Engineers) negotiates and secures the services of an architect-engineer (A-E) firm (if in-house support not available).

B6. In September 1980, the facility design is initiated by the architect-engineer firm.

B7. In March 1981, upon 35 percent of design completion (early preliminary design) a design review is held to review the design documents (drawings, specifications, analysis, cost estimates, etc.).

B8. In August 1981, upon 95 percent of design completion (unchecked final design), a design review is held.

B9. In September 1981, the Invitation For Bid (IFB) documents are distributed to the involved AF components (Base Civil Engineer, AFLC, and user) for a final review. This review is made simultaneously with the issuance of the solicitation (advertisement of project).

B10. In November 1981, sealed bids received during project advertisement period are publicly opened by the Contracting Officer at the designated time and place.

B11. In December 1981, contract award is made provided that specified criteria are satisfied (see AFLCR 78-4 for details).

B12. In January 1982, construction period begins.

If the MCP funds are to be available for FY82, the requirements for the facility must be known by late 1979 or almost two years prior to funds availability. Adding the construction period to this approval period can create a long time period before facility completion. Since the facility equipment funds are approved as a separate package, unnecessary delays can also occur and add complications if any part is not approved.

8.4 RECOMMENDATIONS

1. Seek approval for travel to AFR-800 required meetings to be funded through program funds or given a higher priority within BP 3400/EEIC 40X.

2. Establish definitive funding lines within AFR 800-14 and the PMD's to route facility and IV&V funds to AFLC agencies to establish support capabilities.

3. Insist on full funding to accomplish the AFLC assigned mission within the EEIC 583 line and justify this through an in-house hardware versus software modification cost comparison.

4. With full funding within EEIC 583, reduce the split funding now inherent in the software block change concept.

5. Support JLC efforts to reduce restrictions to multi-year contracts to include incremental funding.

6. Attempt to obtain three-year obligation authority for EEIC-583 funds.

7. Develop a comprehensive set of funding procedures to include any of the above alternatives in the form of an AFLC regulation (AFLCR 800-21 now attempts to do this) and keep it current rather than dissiminating direction through letters, etc.

9. PRODUCT/DATA QUALITY AT TRANSITION

9.1 BACKGROUND

Product quality at system turnover is quite like the weather: everyone talks about it, but no one seems to be able to control it. AFLC has initiated several major undertakings in an attempt to cope with this issue. The single most significant undertaking has been the establishment of AFALD; however, other efforts, such as advocating changes to ASPR's and updates to quality assurance standards (MIL-STD 52779), were directed to this end. And, certainly, progress has been made. However, software continues to be transitioned that has not been thoroughly tested, is without adequate data, and/or without adequate support tools established to carry out the AFLC mission. The intent of this investigation was not to assess the operational suitability of the delivered system, but to assess the supportability of the software in the system, delivered for organic support.

9.2 DISCUSSION

Elements contributing to the supportability of software delivered include, but are not limited to, the following:

- Standardized languages
- Data provided on software/systems
- Availability of support tools
- Standardization and commonality considerations
- Growth potential in the target computer
- Completeness of development (baseline)
- Demonstration of support capability

Consideration of these elements was made to (1) determine the extent the element currently degrades from supportability and (2) investigate any other method for improving product/data quality over and above those actions currently underway. One factor affecting all these elements which would appear to have a major impact on this area is the timing of AFLC support requirements. This will be treated as a separate issue.

9.2.1 Standardized Languages

DODD 5000.29, 5000.29X, 5000.30, and 5000.31 all establish the need for and direction in the use of standard and High Order Languages (HOL) in Embedded Computer Systems. While it is realized that this is a current problem, the Air Force and the DOD community as a whole appear to be making substantial progress in this area. This subject is also discussed in Volume VIII of this report.

9.2.2 Data Provided on Software/Systems

This appears to be the second most pronounced obstacle to organic support (behind manpower). In order to perform transition from contractor to organic software support, the data package or documentation is the necessary vehicle to carry the body of knowledge from one group to another. This area has long been recognized as a problem area in the ECS acquisition process with (1) the data packages generally incomplete, (2) the documentation containing numerous inconsistencies/errors, and (3) data withheld because of proprietary aspects. Also, some data appears to be deliberately withheld by some contractors in order to maintain an advantage in possible follow-up business opportunities.

9.2.2.1 Minimum Data Package

AFLCR 800-21, paragraph 1-19b, describes a minimum set of data required for software support. "System specification" should be added to this list. Other documents which should be considered for procurement are facility descriptions used in the development and planned for the support phase.

Although a minimum data requirements list exists, one problem is that the procurer has no standard by which to assess what should constitute the content of a minimum data package necessary for performing software support. (Data Item Descriptions are not standardized.) Military Standards are available for specifications (MIL-STD 490, 483), but other standards and/or guidance are needed for the other documents.

This need has been recognized within the Air Force, and steps are currently being taken as evidenced by the "Final Report of the Joint Logistics Commanders' Software Workshop", dated 1 October 1979. AFLC

headquarters is also sponsoring a study for "Development of Joint Services Software Acquisition Documentation". These efforts should be strongly pursued as the need definitely exists.

9.2.2.2 Quality at Transition

Even if the desired content for documentation is specified carefully, errors/inconsistencies occurring at management responsibility transition will not be alleviated unless some additional strong measures are taken. The current process requires transferring the responsibility at a specified date in the ECS life cycle from one organization to another. What assurances should the latter group have that the data package is correct before accepting this responsibility? How extensive should the review process be? To expect that a documentation review can be performed in a short period of time before PMRT is unrealistic. The amount of documentation for complex weapon systems is overwhelming, especially if no distinction is made between primary and secondary documentation. For example, the E-3A specifications assimulated so far occupy more than 28 feet of bookshelf space.

For the most part, reviews consist of (1) providing the reviewer with the document approximately one month ahead of the review, and (2) spending a day or two at the review discussing errors/inconsistencies. All too often, discussions center around superficial problems, such as notations, formats, and typographical errors. No meaningful effort is made to correct any technical errors and inconsistencies.

The contention is that additional measures must be taken if the quality of documentation is to be improved. The required in-depth understanding of the documentation cannot be obtained "overnight". Even if the documentation is provided earlier, simply reading the document over and over will not achieve the necessary level of understanding. The recommended approach is that the group to be given the eventual responsibility be required to perform Independent Verification and Validation (IV&V) during Full-Scale Engineering Development (FSED). This IV&V will provide (1) a vehicle for the O&S personnel to gain in-depth understanding of the ECS to properly review and accept the data package at PMRT, and (2) the method successfully used in important programs for flushing out software

problems. Instead of completely depending on another contractor, Government employees can be utilized in the IV&V process. An additional payoff is thereby realized with little change in overall costs.

9.2.2.3 Independent Verification and Validation (IV&V)

The following are activities which would be beneficial for the designated support agency to accomplish during IV&V:

System Specification Verification

- V&V planning
- Requirements analysis
- Documentation review

Tool Development and Maintenance

- Tool evaluation
- Tool development
- Installation and demonstration
- Training
- Tool maintenance

Software Requirements Verification

- Requirements analysis
- Critical requirements identification
- Documentation review

Software Design Verification

- Design analysis
- Performance analysis
- Documentation review

Program Verification

- Code analysis
- Machine level testing
- Documentation review

Software Verification

- Formal testing
- DT&E review
- Documentation review

Special Studies

- Quick turn-around studies
- Design analysis trades

Configuration and Data Management Support

- Configuration management
- Data management

9.2.2.4 Proprietary Implications

The contractor's claim to proprietary data can severely impact, if not negate, any attempt to establish an organic support capability. Implications are that the segment of the software which is proprietary must be supported by the contractor throughout its life cycle. The organization which has the responsibility over the total system is denied the opportunity to understand a segment of the system (although the Government is not a competitor, other contractors may be used during organic support).

Often, proprietary claims are made late in the development cycle when it is difficult to rectify the problem. Requirements must be stated early so that proprietary implications are visible at source selection and may be worked in a competitive environment. The only claim which can be allowed is for those segments developed by the contractor using independent research and development funds. (All software developed with Government funds legally cannot be proprietary.) Whenever ECS procurements are made, there should be a stipulation that if proprietary software is to be used, it must be identified in the proposal. There should also be stipulations that the contract to be negotiated will provide the Government the opportunity to acquire the proprietary data at a specified future date. Whenever selection of the winner is made, proprietary data aspects should be an important negative factor in the selection. If the contractor wishes

to bring in proprietary data during the development phase, he should be allowed to do so only if he agrees to sell the data to the Government at a specified future date. The goal in any ECS procurement should be the elimination of proprietary aspects for the O&S phase. Most of these considerations are covered in ASPR's.

9.2.3 Availability of Support Tools

This is an area that could be helped by the performance of IV&V by the eventual support agency. Numerous problems in this regard have been successfully, but painfully, worked by AFLC organizations in the past (F-15 Radar Data Processor Assembler, various ATLAS compilers, and test pattern generators); however, early involvement would preclude any surprises at PMRT. The IV&V process itself normally provides an additional alternative set of tools for support.

9.2.4 Standardization and Commonality Considerations

This is covered in Volume VIII of this report.

9.2.5 Growth Potential in the Target Computer

This has been a problem in the past (F-111), but does not appear to be now. In discussions with ECS managers, no one brought it up as a major problem with today's systems.

9.2.6 Completeness of Development (Baseline)

The problem here manifests itself primarily in the Electronic Warfare (EW) subsystems that have transitioned (ALR-46 Series, ALQ-131). AFLC has met this challenge by basically adopting an SPO concept within WR-ALC/MMR. It is not anticipated that a major system transfer will present a problem, except in the area of concurrent software changes (contractor on residual tasks, AFLC on updates cited after transition). These problems will have to be worked on an individual basis by a transitional working group and by DPML.

9.2.7 Demonstration of Support Capability

Demonstrations of support capabilities for some support systems have been, or are being, planned (F-15, APR-38, etc.). This concept could be universally applied in conjunction with the in-house IV&V effort suggested above.

9.2.8 Timing of AFLC Support Requirements

Current acquisition practices used by the Air Force require that support systems be firmly identified and specified concurrently with the weapon system requiring the support. Existing directives (AFR 800-14, AFLCR 800-21) provide adequate guidance for inputting support requirements into the development/acquisition process.

The Department of Defense is the agency responsible for approving or disapproving any Air Force-submitted request for a new operational capability. Funding for acquisition of weapon systems to include any support equipment costs is Congressionally controlled. The weapon system acquisition go-ahead is dependent upon the budget responsiveness of Congressional agencies and the target budget as estimated by the Air Force for any Air Force acquisition. Typically, a weapon system cost is preliminarily estimated and all or some portion of that estimate is approved. As the weapon system design and ensuing costs are solidified, a more accurate cost is presented, and likely approved, and thus the target weapon system cost is established. Even with this additional solidification, however, some cost and technical risks still exist with the acquisition of the basic weapon system.

A parallel risk exists with the support system itself. In years past, support systems were simpler and relatively less expensive compared to today's standards. Weapon systems which use computers, with their attendant software, are commonplace and require sophisticated support systems, such as AISF's, that represent a sizeable portion of the total investment. Since both weapon systems and support systems are complex and their acquisition contains risk, overruns are not uncommon. Because of the necessity to forecast complete system acquisition costs to include support systems and equipment, it is necessary that support systems be firmly identified in the early stages of acquisition. Furthermore, there is a basic, bonafide attempt to stay within the target cost limit. Any cost escalation of the basic weapon system is typically met, at least partically, by diverting funds originally budgeted for support systems, documentation, or weapon system quality and testing in an effort not to raise the target costs. (Of course, if the escalation is large

enough, there is little recourse but to ask for a higher target cost). Acquisition of the basic weapon system is paramount in the acquisition emphasis; thus any penalty to support components, from a program manager's viewpoint, is understandable.

Typically, AFLC identification of support requirements is initiated early in the acquisition cycle, with details defined in incremental updates as the weapon system materializes. Unfortunately, weapon system design solidification is not until the Preliminary Design Review (PDR), or later, by which time the target costs are expected to be fairly accurate. Support system design is necessarily vague until the weapon system design is frozen. During this development period when the weapon system is evolving, rationale for defending specific dollar amounts for the support system is weak because the support system cannot be firmly specified. Diverting funds that were originally planned for support system costs makes sense to the program manager because (1) the support system is not firm and the defending rationale is weak, and (2) it is easier and less volatile to divert funds from "inside" the weapon system acquisition project than to defend an overrun to Congressional agencies.

This diversion indicates that AFLC support system quality is at the mercy of the acquisition process itself. While directives provide ample policy/guidance for life cycle cost considerations, costs and schedules may actually drive the entire weapon system acquisition process while life cycle costs are monitored. Unfortunately, it is very difficult to quantify the impact of shortcutting systems testing, documentation, or support system quality upon total life cycle costs. The impact manifests itself to AFLC when operational support of the weapon system is required with documentation which must be updated or endured, untested deficiencies which must be corrected, and poor quality support systems which must be improved or used "as is". On the other hand, it would do no good to have a quality support system to support a nonquality system; thus this discussion does not dispute the acquisition emphasis.

The position that a support system is inadequate is usually accepted only after data has been gathered to prove the inadequacy. Data of this type is not usually available until some sort of operational capability has been attempted and, perhaps, established. Chances are that PMRT

already will have occurred and the original acquisition agency no longer has the responsibility to acquire the support system, so any updates to the support system must be done by AFLC.

In summary, the problem is that acquisition emphasis can cause inadequate support system quality which impacts AFLC support posture for embedded computer systems. One possible solution to this problem is the establishment of joint AFSC/AFLC regulatory guidance that requires the approval of AFLC prior to diversion of funds programmed to meet AFLC requirements. (That is, leave AFSC responsible for the overall acquisition, to include the support system, but not allow support system funds to be spent without the approval of AFLC.) Using this approach, the support system quality would be a direct responsibility of AFLC in terms of requirements definition and cost control. Any weapon system acquisition overruns would be the responsibility of AFSC and any support system acquisition overruns would be the responsibility of AFLC.

9.3 RECOMMENDATIONS

1. Develop an embedded computer resources guidebook which can be used by source selection team members. Among other AFLC requirements this guidebook should delineate support data considerations as well as the methodology to be used in developing the ECS elements.

2. Update the minimum set of data requirements listed in AFLCR 800-21 to include a system specification and software development/support facility description documents.

3. Develop content standards and/or guidance for documents not covered under MIL-STD 490 and MIL-STD 483.

4. Provide continued AFLC support to the joint services effort aimed at defining documentation requirements for software acquisition.

5. Adopt a formalized means of directly and actively involving AFLC in the ECS acquisition cycle sufficiently in advance of PMRT to ensure a high quality of well baselined software and related documentation exist at transfer and that sufficient resources (personnel, training, equipment, facilities, support software, etc.) are timely made available to AFLC to carry out life cycle O&S software support. It is urged that, as part of this approach, AFLC perform predeployment IV&V on development software and demonstrate AFLC software supportability as a

prerequisite for transfer. These provisions should be made part of the AFR 800-4 PMRT plan.

6. Eliminate, through discrimination in the source selection process and through contractual terms in the production phase, proprietary software which is either integral to or used in support of a USAF-maintained ECS.

7. Establish joint AFSC/AFLC regulatory guidance that requires AFLC approval prior to the reprogramming funds earmarked for AFLC requirements to other acquisition areas.

8. Continue to encourage AFLC participation in the requirements definition phase of the acquisition cycle to ensure adequate resources for post-deployment support are defined from the onset. Measures should be taken at AFLC HQ to make available sufficient manpower and skills to define and follow-up these requirements.

10. MANAGEMENT STRUCTURE

10.1 BACKGROUND

Current AFLC management structure is the result of an evolution spanning several years. With few minor exceptions, the structure has not significantly considered support of ECS software to the extent of influencing the structure configuration. That is, the structure was configured to provide support to systems and items with primary emphasis on the hardware involved. The structure was further designed to achieve spare and repair support without extensive regard to engineering development. As the AFLC role in engineering development has changed in recent years, particularly in regard to ECS software support, certain anomalies have surfaced within the AFLC management structure.

Much discussion on this subject and numerous alternatives have evolved in the past few years directed at better aligning the AFLC structure to meet challenges brought about by this new role. Because it would be impossible to objectively assess the numerous organizational interfaces involved in the current and myriad of proposed alignments, this section will attempt only to investigate some of the alternatives and provide insight into their advantages and disadvantages. Two significant organizational realignments recently have been accomplished by AFLC which impact embedded computer support. These are: (1) the establishment of AFALD, and (2) the establishment of an Electronic Warfare (EW) Management Division at WR-ALC (MMR). Because these actions are relatively new and their impact is difficult to assess, no suggested changes to their organizational arrangement will be considered; however, it is strongly recommended that these organizations be staffed at all levels (planning, acquisition, management) with personnel experienced in dealing with ECS problems, with strong emphasis on engineering disciplines.

10.2 DISCUSSION

Two levels of management will be discussed as they pertain to ECS management. These are the HQ and the ALC structure. Each of the organizational alignments investigated will be presented as alternatives.

10.2.1 Headquarters AFLC Structure

The primary agencies within AFLC which have an impact on embedded computer support are LO, XR, MA, and AC. LO (LOEC) is the office of primary responsibility and, therefore, responsible for policy and guidance affecting ECS. AFLC HQ is structured along functional lines which appears a reasonable approach. Then the question may be asked, "Why is organizational structure an issue?" The primary complaints heard from field agencies are:

- Policy and guidance are inadequate.
- Headquarters does not understand the field's problems.
- Responsibility assignment is not in accordance with regulations or good management practices.

Because these complaints span several offices, let us look at the complaints.

While restructuring may offer the most expeditious means of replying to these complaints, a degree of relief is achievable through a conscientious effort to more closely coordinate activities between AFLC HQ and the ALC's. Regularly scheduled AFLC in-house status reviews (e.g., semi-annually) which go beyond the concerns broached in the Log RCS reporting system are suggested as an intensive alternative.

10.2.1.1 Policy and Guidance

The complaint here is more accurately stated as too much guidance. In addition to DODD 5000.29, AFR 800-14, and AFLC implementing regulations, numerous logistics publications (AFLCR 23-42, 23-43, 23-44, 66-17, 66-27, 66-37, 67-17, etc.), data processing directives (AFR 300 Series), and funding documents (AFM 172-1, etc.) contain guidance impacting on ECS support. There is some validity in the argument that there is vaguely stated or confusing guidance; however, AFLCR 800-21, with some exceptions (notably ATE), is a reasonable attempt at stating policy as it now exists. The primary problem appears not to be in disseminating guidance, but in obtaining coordination of policy within the HQ and with other agencies. This is primarily due to parochial considerations and cannot be resolved by this report. One consideration would

be to elevate the status of LOEC to a three-letter office symbol; however, since software engineering is a subset of engineering and the strong need exists to maintain a systems approach to engineering, this would appear to further confuse the issue by separating software and hardware engineering aspects.

10.2.1.2 Field Problems

Headquarters does not understand the field's problems. Of course, this allegation cannot be substantiated or denied. The fact remains, however, that there is not a major civilian field manager from within the ALC's (i.e., MMEC) directly responsible for establishing a software support posture, that has progressed to a Headquarters assignment in a policy-making position. This is encouraged to offset these allegations.

10.2.1.3 Responsibility Assignment

Responsibility assignment is not in accordance with regulations or good management practices. By mutual consent with the customer, this issue is not addressed in this report.

10.2.2 ALC Structure

In considering the ALC organizational structure, four alternatives were examined. In all the considerations, no structure was suggested that would require shifting any workload from one ALC to another. Due to the emotional facets of such a suggestion, it was felt it would detract from the study. These alternatives are:

- Establish a management division for each avionics (e.g., command and control) type of FSC.
- Establish a service engineering organization with all digital hardware and software engineers.
- Establish a software only organization.
- Retain present structure.

10.2.2.1 FSC Management Division

This approach would be more applicable to WR-ALC because of its heavy involvement with avionics item management, but would be somewhat applicable to all ALC's. It is along the lines of the WR-ALC MMR

organization. The approach appears to be working well for MMR; however, it may not work well for other equipment classes. Advantages are:

- Provides for a system engineering approach by consolidating hardware and software engineering.
- Provides for more consolidation of like activities so that more standardization of tools and facilities can be implemented.
- Consolidates expertise for a particular type equipment.
- Collocates engineering, technician, management, and supply activities.
- Could, in cases, reduce the tools available to the system manager to fulfill weapon system level training.

Disadvantages are:

- Will probably impact manpower requirements in overhead positions.
- Dilutes any consolidated core of software expertise now available in MMEC organizations.

10.2.2.2 Service Engineering

This is the alternative which appears to most nearly implement AFR 800-14 from a centralized engineering management standpoint. This is similar to the old service engineering concept used in AFLC prior to the last major MM reorganization. The advantages are

- Affects the consolidation of digital engineering expertise.
- Collocates all digital engineers with the AISF.
- Establishes a total digital system engineering concept to technical problems.

Disadvantage is:

- Separates engineering from supply activites.

10.2.2.3 Software Only Organizations

This alternative was considered for software as a whole and for ATE software only.

10.2.2.3.1 ATE Software. Advantages are:

- Will resolve the current conflicts over organizational responsibilities.
- Will probably reduce manpower requirements in overhead and technical areas.

Disadvantage is:

- Impairs the accessibility to equipment now enjoyed by SSC personnel.

10.2.2.3 2 All Software. Advantages are:

- Establishes a single focal point for software.
- Collocates software engineers with AISF.

Disadvantages are:

- Separates software and hardware engineering and thus impacts the system engineering aspects.
- Separates SSC activities from maintenance equipment.

10.2.2.4 <u>Retain Present Structure</u>

Advantages are:

- Current policy/guidance is applicable to present structure.
- Protects against the uncertainty that would accompany an organizational change.

Disadvantages are:

- Present problems will persist in ATE organizational responsibility conflicts.
- Some duplication of effort is evident impacting manpower.
- Competition for software workload and resources will persist between organizations involved in ECS support.

10.3 ALTERNATIVES

- Establish a management division for each avionics type or Federal Supply Class at the ALC's.
- Establish a service engineering organization with all digital hardware and software engineers at each ALC.
- Establish a software only organization at the ALC's.

APPENDIX A

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action

- Issue: ECS Readiness Support Concept
- Recommendations

From a priority ranking of avionics systems, Fire Control Radars and their associated "core of trained personnel" should be ranked as first priority.

Conduct an extensive review of the current and future ALCs' mission and from this, document their requirement for the use and storage of classified data to include both "Friendly/Blue" and Foreign Intelligence Data. WR-ALC and SM-ALC should receive first priority for this review due to their extensive work in the area of electronic warfare. This should:

a. Identify the type and classification of the various ALC ECS support facilities as a function of both the classified intelligence material handling/storage and the classified nature of the "Friendly/Blue" systems. This effort should include not only a review of the overall facility classification, but also identification of required work areas and conference facilities.

b. Analyze and identify the type, number and level of classification of the personnel required to support each ALC in this area.

c. Document and implement appropriate HQ AFLC direction in the area of specific responsibilities for obtaining and providing the required intelligence support at the various ALCs. Specific consideration should be given to publication of an AFLC implementation regulation for AFR 200-1.

d. Based upon the above work, develop a long-range plan for obtaining, storing, and working with foreign intelligence data command-wide.

Develop, in coordination with operational commands and the intelligence community, a concept of operations for reprogramming critical mission embedded computer systems. The EWIR concept now used for EW reprogramming should be used as a guide.

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Continued)

- Issue: Personnel and Training
- Recommendations

a. Develop, within guidance provided by Headquarters AFLC (e.g., via AFLCR 800-21, AFLCR 400-XX), detailing of the various support concepts and alternatives — and accompanying decision rationale — requisite in arriving at an optimum approach (i.e., a more detailed version of the logic paths sketched for the ALFC GLDT in AFLCR 400-XX). Included should be a clear breakout of governmental and readiness functions. It is recommended that any organic staffing logic used by based upon an average employee tenure of 4-7 years vs. the 15-20 years usually associated with government employees.

b. Develop, within guidance provided by HQ AFLC, specific guidance/AFLC policy regarding the consolidation of resources (including cross-training) across ALC's and ECS's.

c. Develop, within guidance provided by HQ AFLC, a generic breakout of functions and activities required in the software O&S job for a given ECS as well as for a multi-ECS environment (Reference 3-1 provides the rudiments for such a breakout).

d. Develop, within guidance provided by HQ AFLC, a skill level index accompanying position descriptions, and manpower quantity algorithm which tracks with 1a through c above.

e. Develop, within guidance provided by HQ AFLC a step-by-step, time-phased trace depicting the manpower acquisition (authorization) process, including new starts and other additive elements, as well as a responsibility breakdown between HQ AFLC offices, ALC offices, and MES Detachments. Other manpower exercises which are conducted but not related to the authorization process should be discussed for information purposes.

f. Develop, within guidance provided by HQ AFLC an expansion of the CRISP content to include contingency planning for ECR's in the event manpower, funding, MCP's inherent in the primary support concept are delayed or denied.

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Continued)

- Issue: Personnel and Training (Continued)
- Recommendations

g. Conduct a study to evaluate traditional support roles and missions of the various AFLC organizations (i.e., AC, MMR, MMEC, MMET, MA-T) as they relate to computer resources, including the matrix management concept in the ALC's. The result of this study should be a work breakdown structure for the job description above.

Clarify and definitize in USAF-level guidance (e.g., AFR 800-14), the roles and missions of the using command and support command insofar as software O&S is concerned. This guidance should be well keyed to the concepts and alternatives developed above.

On the basis of the WBS developed above, provide guidance to the ALC for organizational structure in MMEC organization and definition of interface functions within the MM-R, MA-T, AC, etc., organizations.

Establish through channels, a means to provide sufficient pre-PMRT manpower and funding for post-deployment posturing, DT&E, IOT&E support, etc.

Establish recruiting activity within each ALC, thus reducing the engineering role in this regard to one of conducting technical interview and deciding amongst candidates. Make provisions as necessary for manpower requirements for activity and funds for TDY, advertising, etc.

Replace the MES Detachment function in the software O&S manpower authorization loop by establishing a manpower screening function within HQ AFLC LOE to approve ALC software O&S ECR requirements.

Take steps to have software manpower removed from the "additive" category and placed in the manpower baseline with other O&M functions.

Take action through HQ USAF to establish CRISP's as formal intra-command MOA's and formal instruments of approval for ECR's.

Continue attempts to establish special categories and high grade authorizations for software engineers (viz. via the Joint Civilian Personnel Management Group studying recruitment, retention and utilization of engineers and the Civil Service Commission).

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Continued)

- Issue: Personnel and Training (Continued)
- Recommendations

  Establish OPR's for ECS software O&S training at HQ AFLC/LOE and at each ALC.

  Establish in HQ AFLC/LOEC a special position (e.g., GS-14 or GS-15) for an expert in ECS O&S who has first-hand experience in the problems confronted by ALC's. This position, which might be rotational in nature, should be filled from the ALC's. The chief role of this position would be to advise the ALC's on their problems and to participate in the HQ decision process.

  Within the WBS developed above, consider adding additional administrative positions for absorbing many of the less technical functions now carried out by the software engineers.

  Encourage rotation of key personnel across ECS's (and even ALC's) to help in keeping these invaluable resources challenged as well as to accelerate the training process for the more junior employees.

  Establish a more structured communications loop between HQ and the ALC's through in-house status/problem reviews.

- Issue: Microprocessors and Firmware Support
- Recommendations

  Formulate a joint AFSC/AFLC regulation concerning microprocessors and firmware definitions, concept of operations, configuration management practices, policies, and procedures. This should include policies on HOL's and data requirements and the need for firmware DID's.

  Provide support for the development of an ADA language for microprocessors.

  Provide guidance for the incorporation of microprocessor and firmware implications into the logistics planning process.

  Insist that AFSC provide data on microprocessors and firmware, sparing requirements, storage environments, shelf life, and parts agreements.

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Continued)

- Issue: AFR-800 vs. AFR-300 Acquisition/Support
- Recommendations

  This acquisition issue is currently being worked by the Joint Logistics Commands; therefore, no alternatives are suggested other than to continue support of the JLC initiatives toward adoption of the proposed changes to DOD Directive 5000.29.

- Issue: Configuration Management
- Recommendations

  Review the suitability of the CPIN system for controlling baselining documentation — particularly for computer programs employed in a multi-version environment involving more than a single ECS and a single weapon system.

  Review the O/S CMP outline recommended in AFLCR 800-21 with the thought of reorienting it more toward specific, detailed "procedures" rather than toward top level "planning". The CRISP CM section might warrant change to better accommodate the CM "planning" aspects. Consideration should also be given to modifying both these outlines to accommodate the various types of software that may be addressed in a weapon system level O/S CMP (i.e., OFP, ATE, etc. — including necessary support software).

  As suggested in Personnel and Training, formulate a generic set of software change activities and associated O&S functions which are applicable across the five ECS types. The CRISP and O/S CMP outlines presented in AFLCR 800-21 should be modified to reflect this partitioning. The work breakdown structure at the ALC's should also be adjusted to be more closely aligned with these functions/activities.

  Implement the recommendations tendered in Product/Data Quality at Transition to assure suitable baseline descriptions are available at ECS PMRT and are kept current (with respect to the physical media) over the life cycle.

  Through close coordination with AFSC, encourage the: pre-deployment use of the procedure format evolving from detailing the configuration management provided in AFR 800-14 and AFLCR 800-21 into ALC division and branch level procedures discussed in general recommendations,

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Continued)

- Issue: Configuration Management
- Recommendations

  and the tools selected in implementing the recommendations tendered in Product/Data Quality at Transition sited above.

  Re-examine the requirements set forth in AFLCR 800-21 and 66-15 regarding the use of Material Deficiency Reports (MDR's), Materiel Improvement Projects (MIP's) and TCTO's to report, track and release ECS software changes. A "tailored" process more closely attuned to the software change cycle (for emergency, urgency, routine — and block change concepts) appears in order.

  Re-evaluate the manpower and staffing plans for each ECS currently entering the inventory to assure that proper CM resources (tools, personnel, equipment and facilities) are programmed. Emphasize, where appropriate, the import of effective life cycle CM.

  Assure that the training planning recommended in Personnel and Training adequately addresses CM requirements.

- Issue: Facility Planning/Funding/Maintenance
- Recommendations

  Develop a coordinated set of AFLC/AFSC guidelines for establishing and maintaining post-deployment software support facilities. These guidelines should address the gamut of planning, development, integration, demonstration, and maintenance activities as well as documentation requirements necessary to ensure that a timely, effective, and efficient capability results. The Software Acquisition Engineering Guidebook for Software Development and Support Facilities recently developed for ASD provides a solid basis for such guidelines.

  Insist that a support facility concept and requirements study be performed during the conceptual/validation phases of each major program where embedded computer resources are involved to establish the support concepts and tradeoffs which need to be considered. This action, which should be under the advocacy and implementation of AFALD with close interaction with and support from AFLC/LOEC and the ALC's, should be fully coordinated with/approved by all MAJCOMS and interservice agencies involved.

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Continued)

- Issue: Facility Planning/Funding/Maintenance (Continued)

- Recommendations

As recommended in Section 3.3, take action to establish the CRISP as a USAF-wide MOA for post-deployment ECS resources (viz. support facilities). It is suggested that a request be submitted to the JLC to establish a joint panel to assess the appropriateness of this recommendation.

Modify AFR 800-14 and other appropriate guidance to more clearly identify the funding responsibilities associated with post-deployment software support facility acquisition and O&M.

Develop a PMD/PMP/ILSP checklist which can be used by HQ USAF, AFLC, AFALD, and field agencies participating in ECS acquisition to ensure that these documents properly address support facilities. USAF/LOEC should be encouraged to non-concur on all PMD's which do not adequately address post-PMRT support facilities.

Incorporate facility planning and funding as part of the DSARC process – including these as specific items in the "DOD Embedded Computer Resources and DSARC Process Guidebook."

In concert with recommendations tendered in Section 9.3, software support facilities should be established within AFLC as early as possible in the acquisition cycle to capitalize on the benefits of permitting AFLC to carry out predeployment activities.

- Issue: Funding

- Recommendations

Seek approval for travel to AFR-800 required meetings to be funded through program funds or given a high priority within BP 3400/EEIC 40X.

Establish definitive funding lines within AFR 800-14 and the PMD's to route facility and IV&V funds to AFLC agencies to establish support capabilities.

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Continued)

- Issue: Funding (Continued)
- Recommendations

  Insist on full funding to accomplish the AFLC assigned mission within the EEIC 583 line and justify this through an in-house hardware vs. software modification cost comparison.

  With full funding within EEIC 583, reduce the split funding now inherent in the software block concept.

  Support JLC efforts to reduce restrictions to multi-year contracts to include incremental funding.

  Attempt to obtain three-year obligation authority for EEIC 583 funds.

  Develop a comprehensive set of funding procedures to include any of the above alternatives in the form of an AFLC regulation (AFLCR 800-21 now attempts to do this) and keep it current rather than dissiminating direction through letters, etc.

- Issue: Product/Data Quality at Transition
- Recommendations

  Update the minimum set of data requirements listed in AFLCR 800-21 to include a system specification and software development/support facility description documents.

  Develop content standards and/or guidance for documents not covered under MIL-STD 490 and MIL-STD 483.

  Provide continued AFLC support to the joint services effort aimed at defining documentation requirements for software acquisition.

  Eliminate, through discrimination in the source selection process and through contractual terms in the production phase, proprietary software which is either integral to or used in support of a USAF-maintained ECS.

  Establish joint AFSC/AFLC regulatory guidance that requires AFLC approval prior to the reprogramming funds earmarked for AFLC requirements to other acquisition areas.

Table A-1. Recommendations Which Can Be Implemented By Directive or Direct Management Action (Concluded)

- Issue: Product/Data Quality at Transition (Continued)
- Recommendations

  Continue to encourage AFLC participation in the requirements definition phase of the acquisition cycle to ensure adequate resources for post-deployment support are defined from the onset. Measures should be taken at AFLC HQ to make available sufficient manpower and skills to define and follow-up these requirements.

- Issue: Management Structure
- Recommendations

  Establish a management division for each avionics type or Federal Supply Class at the ALC's.

  Establish a service engineering organization with all digital hardware and software engineers at each ALC.

  Establish a software only organization at the ALC's.

Table A-2. Recommendations Which Will Require Program Implementation for Improvement

- Issue: ECS Readiness Support Concept
- Recommendations

  Initiate action to provide a stimulus and effectiveness monitoring capability for key avionics systems.

  At the same time, emphasis should be placed on documenting and developing, as an integral part of the stimulus/monitoring equipment, a preemptive engineering and QRC support capability.

  Training and maintaining within each support facility a core of expertise in the areas described in alternatives above.

- Issue: Personnel and Training
- Recommendations

  Develop a top level training plan, in coordination with ATC, AFIT, etc., for ECS O&S engineers and managers. The plan developed by HQ AFLC/LOEC in 1976 represented a good start in this regard. It is strongly urged that a year to 18 month formal training program (such as currently conducted for flight training, maintenance officer's school, logistics management school, etc.) be developed for software engineers and a 2-4 week course for software managers.

  Explore more effective means of using the networks available to AFLC for training and cross-training devices.

- Issue: Microprocessors and Firmware Support
- Recommendations

  Develop and install a standard, well-equipped, growth-oriented microprocessor laboratory at each of the five ALC's.

  Establish a joint AFSC/AFLC/Industry study group to standardize identification and labeling of programmed and programmable devices.

Table A-2. Recommendations Which Will Require Program Implementation for Improvement (Continued)

- Issue: Configuration Management
- Recommendations

  Detail the configuration management provided in AFR 800-14 and AFLCR 800-21 into ALC division and branch level procedures — advisedly in the form of operating instructions (OIs). Action should be taken by HQ AFLC/LOE to assure that such procedures are consistent across like types of ECS's (i.e., OFP, EW, ATD, ATE, CE). These OI's should be employed as items for AFLC functional inspections.

  To enhance accuracy, speed and cost effectiveness, develop a common set of CM tools (e.g., data management systems, requirements tracing tools, library systems) across ALC's — and, where applicable, across ECS types.

  Conduct a trade-off analysis to evaluate centralized change management vs. a decentralized process (for CE and ATD). Roles and missions of involved agencies should be carefully considered. If split software support is determined necessary for a special situation, then support should be aggregated at one location which CM performed as a consolidated/coordinated effort.

- Issue: Product/Data Quality at T ansition
- Recommendations

  Develop an embedded computer resources guidebook which can be used by source selection team members. Among other AFLC requirements this guidebook should delineate support data considerations as well as the methodology to be used in developing the ECS elements.

  Adopt a formalized means of directly and actively involving AFLC in the ECS acquisition cycle sufficiently in advance of PMRT to ensure a high quality of well baselined software and related documentation exist at transfer and that sufficient resources (personnel, training, equipment, facilities, support software, etc.) are timely made available to AFLC to carry out life cycle O&S software support. It is urged that, as part of this approach, AFLC perform predeployment IV&V on development software and demonstrate AFLC software supportability as a prerequisite for transfer. These provisions should be made part of the AFR 800-4 PMRT plan.

REFERENCES

2-1. "ECS Support Posture Classified Report" (U)

2-2. F-16 Threat document, prepared by AF/IN, available through HQ USAF, Attn. AF/INYW.

3-1. OMB Circular, A-76, AFM 400-2, DOD 4100.15.

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